BBC

SHOULD YOU UPGRADE YOUR BRAIN?

Science Focus

IF YOU DON'T READ THIS, YOU'LL BE GUTTED

Could we divert an
EARTH-BOUND ASTEROID?

Big ideas for
GREENER, FASTER TRANSPORT

The way to
SAVE OUR WILD BEES

EAT YOURSELF HAPPY

How the microbes in your gut hold the key to health and happiness

(and what you can do to nourish them)

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Amazon on fire
Could the world's biggest rainforest become a desert?

Space atlas
The telescope that will map the Milky Way

Heart repair
New technique fixes damage after heart attack

MAGNIFICENT
SEVEN

SEE THE FUTURE IN DETAIL

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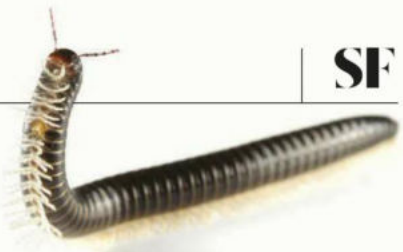

Why do millipedes have so many legs? →p80

FROM THE EDITOR

This will surprise no one, but I'm not a fan of diets. My feeble self-control means that any diet I go on is doomed to fail. Still, with a few notable exceptions, studies show that diets rarely lead to lifelong change. So I've given up on them. That said, I do think about what I can do to age healthily: to keep my fleshy husk out of hospital and make sure my mind stays in good nick. And it looks like there might be a new school of thought that even I can get behind. The more you eat, the healthier you'll be.

Unfortunately, I don't mean eating more in terms of quantity, but more in terms of variety. You are what you eat, the old adage goes, and if you eat a diverse assortment of fruit, veg, nuts and seeds then the bacteria that live in your gut will be diverse too. And that's a good thing, it seems. The variety of creatures in your gut have been linked to how much you weigh, how tired you feel, and how likely you are to get ill, among many other things. And now, it seems there's good evidence for a link between the bugs that populate your digestive system and the health of your mind. It sounds fantastical, but we know there are all sorts of nerve and chemical pathways that connect your gut to your brain. So grab a healthy portion of fruit and veg, and dig in to our cover feature on p48.

Daniel Bennett, Editor

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CONTRIBUTORS

JOCELYN TIMPERLEY
In this new regular section, climate and energy reporter Jocelyn gives us the lowdown on the latest environmental news. → p22

DR LUCY MADDOX
Feel like you need a brain upgrade? Clinical psychologist and writer Lucy looks at the promise – and potential pitfalls – of brain-computer interfaces. → p72

DR STUART CLARK
A joint mission between NASA and ESA will intercept and hopefully change the trajectory of an asteroid. Astronomy writer Stuart finds out exactly how they'll do it. → p64

DR SAMANTHA ALGER
Wild bees are under threat. But what can we do to help them? Ecologist Samantha explains what her research has uncovered. → p58

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ON THE BBC THIS MONTH...

Crowd Science: Is A Vegan Diet Better For Your Health?
What effect does eating meat and dairy substitutes have on your health? The team goes vegan to find out. BBC World Service, 27 September, 8:30pm.

Arctic Academy
A group of teens from West Lothian take part in an expedition to the North Pole where they'll see the effects of climate change first-hand. BBC Scotland (available on iPlayer), 5 October.

The Art Of Innovation
Sir Ian Blatchford and Dr Tilly Blyth at the Science Museum present this Radio 4 series exploring the often overlooked relationship between art and science. BBC Radio 4, 16 September.

COVER: MAGIC TORCH THIS PAGE: GETTY X2, THE BOARD OF TRUSTEES OF THE SCIENCE MUSEUM

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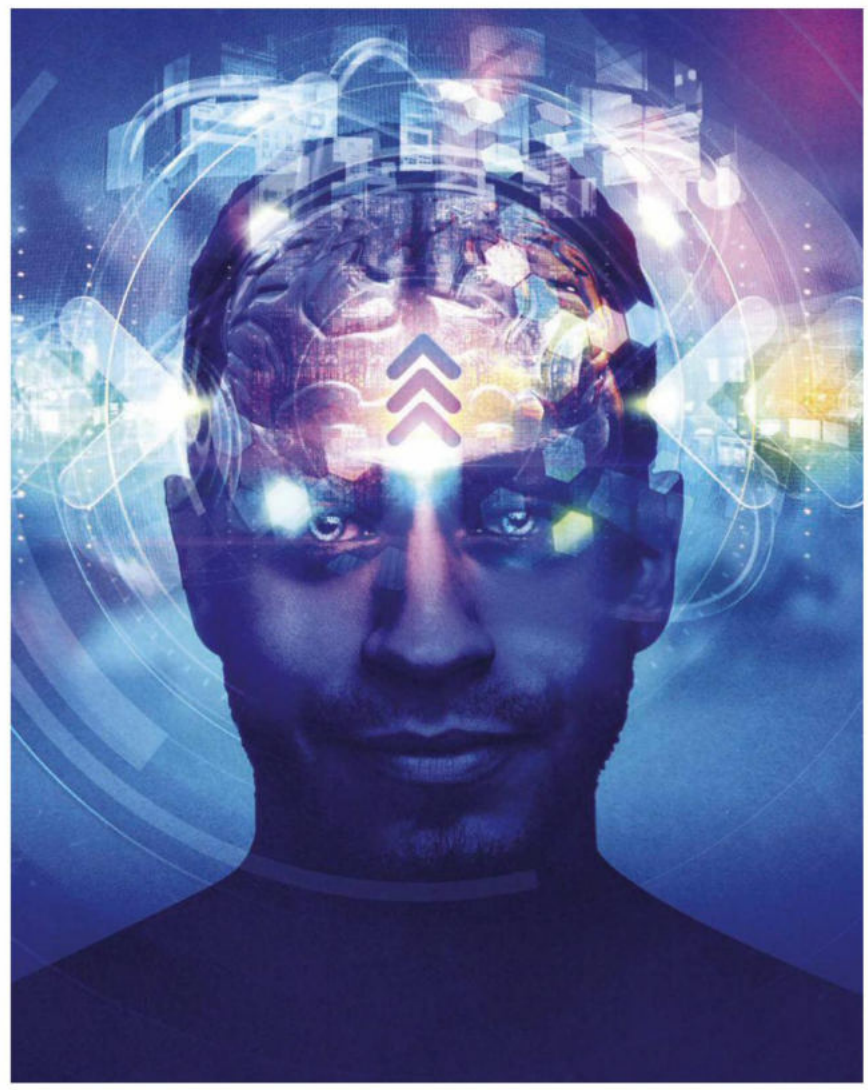

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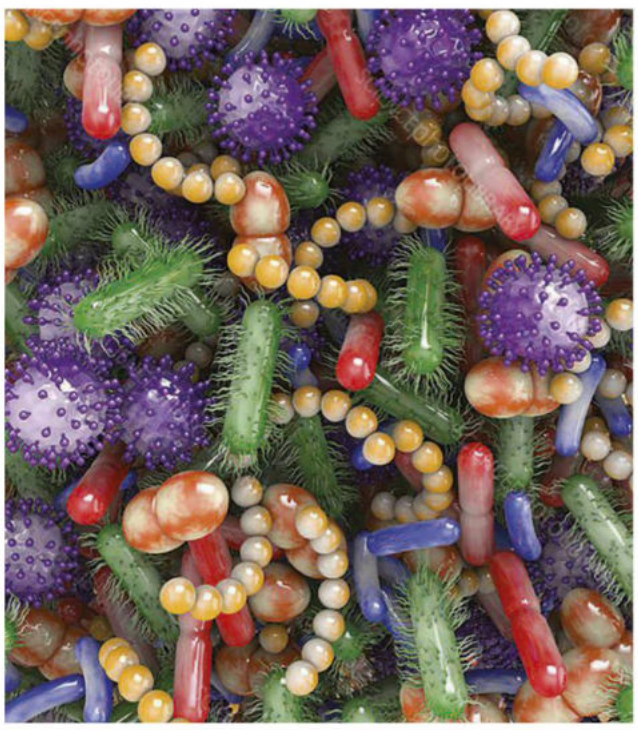

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SAMANTHA ALGER

“If we have a messy lawn, we’re supporting bees, and that’s a beautiful thing”

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Can’t wait until next month to get your fix of science and tech? The Science Focus website is packed with news, articles and Q&As to keep your brain satisfied.
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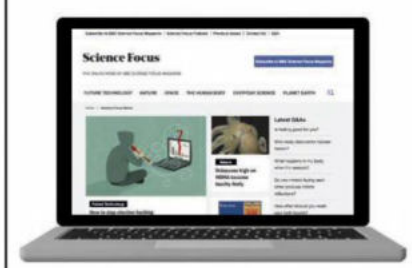

EYE OPENER

Hell hole

KARAKUM DESERT, TURKMENISTAN

The Darvaza gas crater, aka 'The Gates of Hell', has a mysterious past. It is thought to have formed in the 1960s, when engineers drilled the site for natural gas. The sudden upward movement of gases caused a dramatic cratering – the Darvaza crater is 69m wide and 30m deep – and released gas into the air.

"About 10 years after the cratering happened, it was still venting gas," says Mark Ireland, a lecturer in energy geoscience at Newcastle University. "So local geologists purposefully lit it to burn off the gases."

The crater was expected to burn for a matter of days, but is still alight now, some four decades on. And it's hard to predict when the crater will burn out.

"We're missing a lot of scientific data about it," says Ireland. "But it's reported that there is life in the crater: certain microbes like certain conditions. Maybe we could learn something about the extremes where life can survive."

SHUTTERSTOCK

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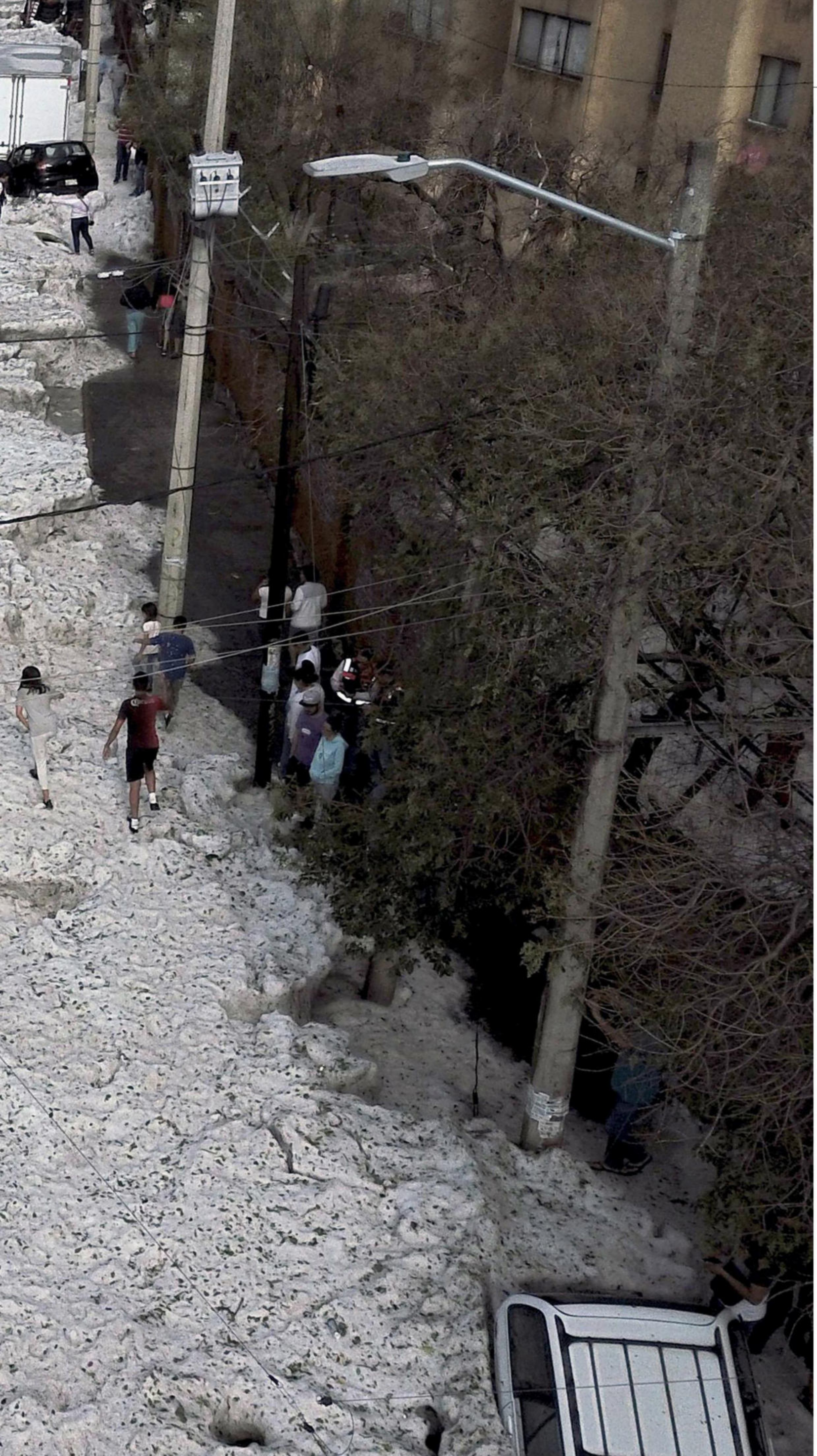
14 de AGOSTO



EYE OPENER

All hail!

GUADALAJARA, MEXICO

The mountain city of Guadalajara, capital of the Mexican state of Jalisco, is home to around five million people. With a subtropical climate, summers in Guadalajara are hot and wet: in the days before this picture was taken, temperatures had been around 31°C, which is about average for the time of year.

But on the morning of Sunday 30 June this year, the city awoke to streets covered in ice up to 1.5m deep. The hailstorm that caused this scene was thought to have been caused by a band of low pressure moving across Mexico, combined with the moist air that comes with summer time in Guadalajara. The governor of Jalisco, Enrique Alfaro Ramírez, tweeted that he had never witnessed scenes like it.

Thankfully, no one was injured during the storm – although hundreds of homes were damaged, and dozens of cars were swept up in the flood of ice.

GETTY IMAGES

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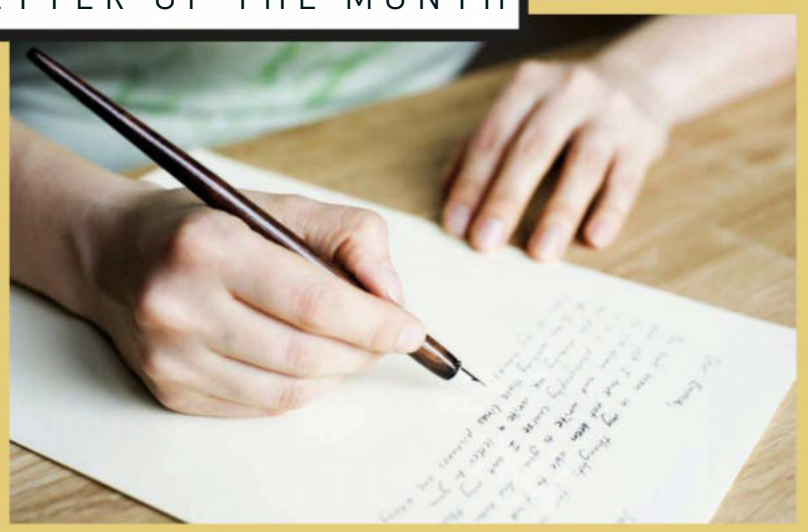
LETTER OF THE MONTH



Good handwriting

I greatly enjoyed reading your feature 'Digital vs analogue' (Summer, p62). As a millennial, I've been brought up with technology, and at university in 2012 everyone had a laptop. I'd often sit through lectures surrounded by the sound of fingers tapping away on keyboards, but I never saw the appeal.

There is a value to handwriting. We are forced to move more slowly, which gives us time to think and to absorb the information we're presenting.

I know not everyone will share my passion for handwriting, but the practice has worth. Perhaps we should start to think more about how digital and analogue can work together. Technology has some amazing strengths, but sometimes, it helps to take a step back, move a little more slowly and think before we write.

And yes, I'm aware of the irony of expressing this opinion via email, but I did write notes on paper first!

Tamsin Nicholson, via email

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a set of **Skullcandy Push True** wireless earbuds. These in the ear speakers weigh just 54g but with their 9.2mm-diameter drivers manage to pack a lot of sound into their small, lightweight bodies. They come with 'ear fins', to ensure they stay securely in place, and a colour-coordinated charging case to make keeping them on full power quick and easy.

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Generation game

In response to your podcast episode 'What does a world with an ageing population look like?', I think we already know. It's clear that today's young people feel we are living too long and that older people feel on the outside of today's society. For example, try to buy suitable traditional clothing and shoes for older people – it's as if they don't exist any more. Also, go in any supermarket and most of the food items on display are geared to families with the modern tastes.

Veronica E Williams, *via email*

'It's what the cool kids do'

In 'The truth about E-cigarettes' (Summer, p22), Prof John Britton mentions that the increase in vaping could be producing a whole new generation of smokers. I think he might be right. I recently saw my seven-year-old granddaughter pretending to vape using one of her colouring pencils. When I asked what she was doing, she said that she had seen people in the street doing it. So despite her being raised in a household in which nobody smoked, she was being influenced by vapers. Could this lead to smoking in later life? Who knows?

Richard Gregory, *via email*

Stigma or semantics?

I think that the writers of the *Reality Check* on whether we should compare obesity to cancer (August, p36) are indulging in semantics. Obesity may be a disease, but becoming obese is a lifestyle choice, as is remaining obese. Anyone who looks in people's shopping baskets will see that those of the obese contain very little fruit or fresh veg, and lots of processed foods and sugary drinks. We need to be more direct with the message about obesity, and I congratulate Cancer Research UK (CRUK) on their campaign.

M A Keeling, *via email*

"WE NEED TO BE MORE DIRECT WITH THE MESSAGE ABOUT OBESITY"

This letter provides almost the perfect illustration of how CRUK's campaign, and the associated media coverage, has emboldened people to express simplistic, stigmatising opinions about obesity and people of higher weights.

Assuming people have higher body mass indexes because they make 'bad' food choices demonstrates a lack of awareness of the complexities involved. The research is clear: an individual's weight is influenced by many factors, including biology, psychology, social structures and environments. This means that we are not all presented with the same 'choices' and our bodies respond differently to the food we eat.

Holding CRUK accountable for promoting unhelpful, ill-informed and harmful ideas about obesity is not about indulging in semantics – it's about highlighting that obesity is a complex social issue with many causes, not an individual failing.

Oli Williams, Lesley Gray and Helen West, *BBC Science Focus* contributors

"BEES PROVIDE ONE OF EVERY THREE BITES OF FOOD. THEY PROVIDE POLLINATION SERVICES FOR MOST OF THE FOOD WE EAT"

SAMANTHA ALGER, p58

READERS' BUZZ

Your views on the burning science topics of the month

In the September issue, we discussed whether pet cats should be kept indoors. We then asked *BBC Science Focus* followers on Twitter (@sciencefocus) for their thoughts on the subject...

SHOULD CATS BE KEPT INDOORS?

GETTY IMAGES

Fran I personally believe that cats should be kept inside, with monitored outdoor access (via walks or 'catio' enclosures) because it increases their lifespan.

Jazmin Keep them indoors and have them on a lead if you take them out. They really impact the environment!

Jem My cats have access to the outdoors. It's not without risks but I'd rather they had a shorter, happy life than a long, dull one plagued by the health issues caused by sedentary behaviour.

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DISCOVERIES

PIONEERING GEL COULD MEND DAMAGE AFTER HEART ATTACK

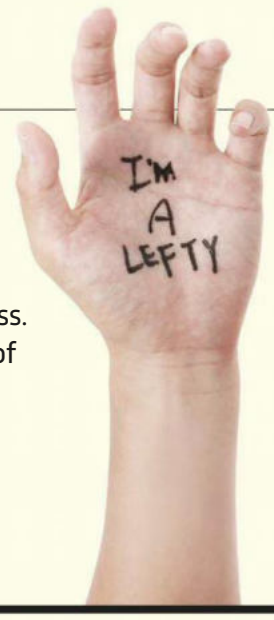
World-first trial shows promise for pioneering treatment following heart attacks

There are more than 100,000 hospital admissions in the UK due to heart attacks every year, but there are few effective treatments for repairing the resulting damage to cardiac tissue. Following a heart attack, scar tissue can develop which can reduce the performance of muscles and eventually lead to ▸

Visualisation of a heart attack, in which blood flow to the heart is interrupted

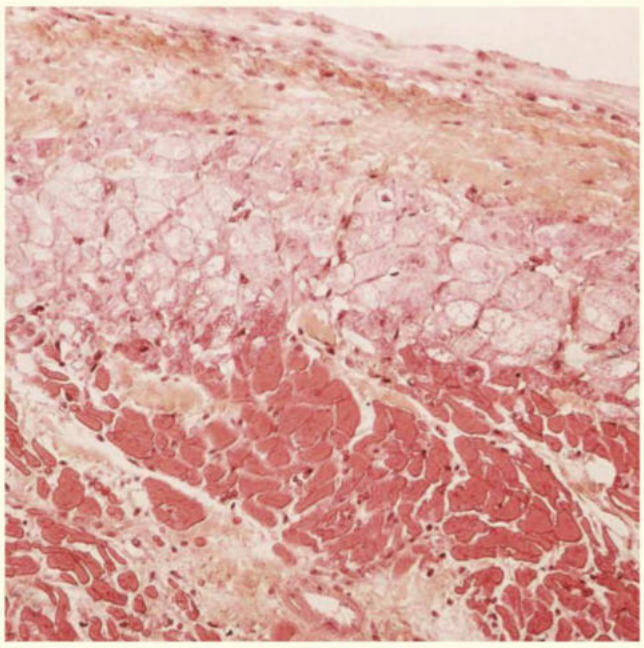
SCIENCE PHOTO LIBRARY, GETTY IMAGES

News in brief



GENES FOR LEFT-HANDEDNESS IDENTIFIED

Researchers at the University of Oxford have identified areas of the human genome associated with left-handedness. The team made the discovery after analysing the genomes of 400,000 people, including more than 32,000 left-handers, stored in the UK Biobank database. They found four genetic variants that contribute to left-handedness. Three of these are associated with proteins involved in the structure and development of the brain.



In this microscope image of heart tissue, the darker regions along the bottom are muscle fibres that have died following a heart attack

Prof Karen Christman led the development of VentriGel

SCIENCE PHOTO LIBRARY, GETTY IMAGES, DAVID BAILLOT/UNIVERSITY OF CALIFORNIA, SAN DIEGO

heart failure. Now, researchers at the University of California, San Diego think they may have a solution – an injectable hydrogel that can form a scaffold around damaged cardiac muscle and encourage the growth of healthy, new tissue.

Dubbed VentriGel, the material has passed its initial safety trials. It is made from the natural scaffolding of cardiac muscle tissue – also known as extracellular matrix, or ECM – which is taken from pigs. The tissue is then stripped of muscle cells, freeze-dried and milled into powder form. It can then be turned into a fluid that can be easily injected into heart muscle in a minimally invasive procedure.

The team tested the gel in a preliminary study of 15 patients who had sustained moderate damage in the left chamber of the heart following a heart attack. All 15 were experiencing mild to moderate heart failure following a heart attack, with half suffering a heart attack within the past year.

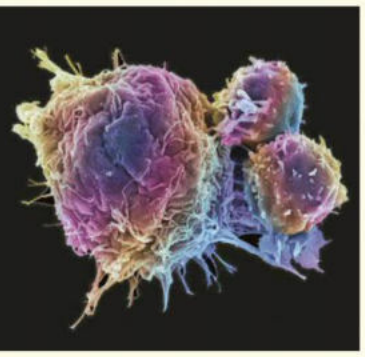
The patients all took a six-minute walking test as well as a heart function assessment and a heart health questionnaire before receiving up to 18 injections of VentriGel into the damaged region via catheter.

The researchers then monitored the patients' progress for six months after treatment, repeating the tests at the three-month and six-month marks.

"Although the study was designed to evaluate safety and feasibility and not designed to show whether VentriGel effectively helps improve heart function, we observed some improvements in patients," said senior author Prof Karen Christman. "For example, patients could walk longer distances. We also observed signs of improving heart function in patients who experienced a heart attack more than one year prior to treatment."

CANCER IS LEADING CAUSE OF DEATH IN RICH COUNTRIES

A study of more than 160,000 adults from low, middle, and high-income countries carried out by researchers at Laval University, in Quebec has found that cancer has overtaken heart disease as the leading cause of death in rich countries, accounting for 26 per cent of deaths worldwide. Heart disease remains the leading cause of death worldwide, accounting for more than 40 per cent of all deaths.



PSYCHOLOGY

Testosterone may not be linked to empathy

Researchers have poured cold water on the idea that people with increased testosterone have reduced empathy. The study was motivated by the fact that five times as many males as females are diagnosed with autism.

"Of course, the primary suspect when we have something that is sharply differentiated by sex is testosterone," said Dr Gideon Nave at the University of Pennsylvania, who led the study.

One theory for this sex difference in autism diagnosis is that autism represents an exaggeration of 'male' tendencies, characterised by a thinking style that's geared more towards systemising than empathising.

This 'extreme male brain' hypothesis has been supported by previous studies that found a connection between increased testosterone and reduced cognitive empathy – the capacity to read the emotions of others, which is characteristically impaired in people with autism. However, these studies were limited by small sample sizes, and the difficulty of determining a direct link. In this new study – the largest of its kind – Nave and colleagues recruited 643 healthy men, giving them either an application of testosterone gel or a placebo. The men's empathy levels were then measured using questionnaires and behavioural tasks. In one task, they were shown a photo of an actor's eyes and asked to select the emotional state that best matched their expression.

But the researchers found no evidence for a link between testosterone levels and empathy. "Our results unequivocally show that there is not a linear causal relation between testosterone exposure and cognitive empathy," said Dr Amos Nadler at Western University in Canada, who was involved in the study. However, this doesn't rule out the possibility that testosterone could still be related to empathy in a more indirect way.

"It seems that if testosterone does have an influence, the effect is complex, not linear," said Nave. Meanwhile, the sex difference in autism diagnosis remains something of a mystery. "For now, I think we have to embrace our ignorance on this," he added.

Some scientists have criticised the study, arguing that testosterone gel may offer different results from testosterone exposure in the womb.

GETTY IMAGES X3 ILLUSTRATION: GABRIEL SILVERA

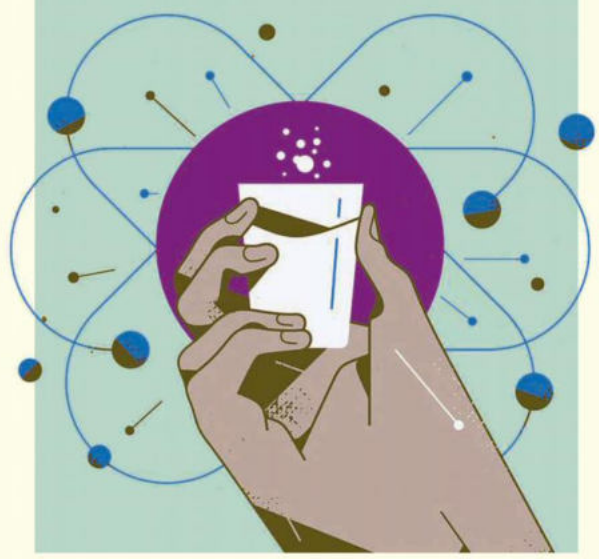
They did what?

Vodka distilled from crops grown in Chernobyl

WHAT DID THEY DO?
Researchers from the University of Portsmouth have created a brand of artisan vodka using mineral water and rye taken from an area of the Ukraine that has been abandoned since the Chernobyl nuclear disaster. Fittingly, they called it ATOMIK.

WHAT DID THEY FIND?
Though they found some signs of slightly elevated levels of radioactivity in the grain, the finished vodka was confirmed to be radiation-free in a series of tests carried out at the University of Portsmouth and the University of Southampton, as well as in an independent wine and spirits testing lab. The only radioactivity detected in the alcohol was natural carbon-14, which was at the same level that would be expected in any spirit drink.

WHY DID THEY DO THAT?
The team wanted to investigate the potential transfer of radioactivity to crops grown in the Chernobyl Exclusion Zone to determine whether it is now suitable for agricultural use.



SCIENTISTS PAWS-ITIVE WE'VE ALTERED DOGS' BRAINS

Over the centuries, humans have bred dogs for different tasks, like hunting, herding or companionship. This has led to huge variation in our pooches' physical characteristics. But new research suggests that our meddling has shaped their brains as well.
A US-based team used an MRI scanner to study 62 dogs from 33 breeds, and found that brain anatomy varied considerably, and seemed to correlate with the tasks that the dogs had been bred to carry out. However, the variations don't seem to be linked to the size of the animal's brain, or its skull shape.

Trending

YOUR GUIDE TO WHO'S SAYING WHAT ABOUT THE HOTTEST TOPICS IN THE WORLD RIGHT NOW

#OrganDonation Week2019

The first week in September marked organ donation week – a campaign set up to encourage members of the public to share their stories of organ transplantation and their own personal decisions regarding organ donation.

Stephanie Slater MBE
@StephESlater

I was given the gift of sight in 2016 thanks to my donor and her family! It really has changed my life! Forever grateful! Thanks to @LivOphth St.Paul's Eye Unit for the expert and passionate care I receive too. Have you shared your wishes??

Lucy
@ResearcherLucy

Sadly every day at least three people die whilst waiting for a transplant. A figure which could change if more of us registered. Even with the law change, it is important that your family know your wishes.

#LochNessMonster

After months of analysing DNA extracted from water samples taken from Loch Ness, researchers from New Zealand have ruled out the possibility of Nessie being a catfish, sturgeon, Greenland shark, or plesiosaur. The only plausible remaining candidate is a giant eel.

A/Prof Samantha Pugh
@SamLP

I love the #LochNessMonster story. All science has proved is that we can't find it, which is not the same as proving it doesn't exist!

Lisa Farrell
@ResearchLisa

Duh, it's a mythical creature and therefore transcends DNA. Leave Nessy alone and let us believe. #lochnessmonster

KEEP IN TOUCH

@SCIENCEFOCUS

#EuniceFoote

This year is the 200th anniversary of the birth of Eunice Foote, a little-known pioneer of climate research and first person to make the connection between carbon dioxide levels and climate change.

Request a Woman Scientist
@RequestWSTEMM

You've heard of #RosalindFranklin but how about #LiseMeitner #EuniceFoote #ChienShiungWu? The Matilda Effect: the refusal to acknowledge scientific discoveries made by women researchers. Read on, then share a #ScientificDiscovery you've made.

Joseph DeMarco
@JosephJDeMarco

In 1856, Eunice Foote – a scientist and activist – was the first woman to connect carbon dioxide and climate change. This was 3 years before Tyndall, the man that is widely credited as the first to discover this connection.

#Dorian

Hurricane Dorian wreaked devastation across the Bahamas with winds reaching almost 300km/h before lashing the coast of North and South Carolina.

Josh Morgerman
@iCyclone

I mean it when I say #Hurricane #DORIAN is worst cyclone disaster I've personally witnessed since Super Typhoon HAIYAN. Scale of destruction is jaw-dropping – you can't get your head around it – and task ahead is Herculean. They need HELP. Consider pitching in.

Bill McKibben
@billmckibben

Since records began in 1851, #Dorian is the slowest moving major hurricane (something that scientists have linked to a warming climate). This is what happens when a storm just sits like a blender over the Bahamas.

Macaques suffer from anxiety too

GETTY IMAGES X3, ALAMY, CARLYN IVERSON/WNOAA CLIMATE.GOV, NASA

NEUROSCIENCE

A treatment for anxiety is all in the mind

Boosting levels of a protein that stimulates neuron growth could offer new hope

A protein that is found naturally in the brain could decrease behaviours associated with anxiety, according to US researchers. The protein, neurotrophin-3, was found to stimulate neurons to grow and connect within the dorsal amygdala – an area of the brain involved in emotional responses.

The team selected a group of young rhesus macaques who displayed signs of 'dispositional anxiety' – the tendency to feel unduly anxious, or perceive a wide range of situations as threatening. They were able to identify neurotrophin-3 as one of the molecules related to this type of anxiety. They used a modified virus to boost levels of the protein within the dorsal amygdala, and found that the macaques' anxiety decreased.

"Neurotrophin-3 is the first molecule that we've been able to show in a non-human primate to be causally related to anxiety," said Andrew Fox, co-author of the study and assistant professor in the department of psychology at University of California, Davis. "It's one of potentially many molecules that could have this effect. There could be hundreds or even thousands more."

It is estimated that some three million people in the UK have an anxiety disorder, and more than 1 in 10 of us are likely to have a disabling anxiety-related condition in our lifetime. "These disorders are some of the leading causes of disability and days lost to disability," said Fox.

Currently, patients living with anxiety are offered a range of treatments to manage their condition, but there are no guaranteed routes to overcoming the disorder permanently.

SWEET DREAMS, IT'S IN YOUR GENES

We all need sleep, with adult humans requiring seven to nine hours a night, yet remarkably little is known about the genetics behind it. Now, scientists at the University of California have identified a gene that has an impact on how much a person sleeps. The gene, called ADRB1, was found by studying a family whose members need just six hours of shuteye a night. The scientists say that this research could assist in the development of new drugs to help with sleep. "Not getting enough sleep is linked to an increase in the incidence of many conditions, including cancer, autoimmune disorders, cardiovascular disease, and Alzheimer's," said Ying-Hui Fu, who took part in the study.

In numbers

7

The number of northern white rhino eggs fertilised using frozen sperm taken from the now-dead last male of the species.

17,000 YEARS

The age of roundworm DNA found in ancient puma scat, making it the oldest parasite ever recorded.

1HZ

Utah's Castleton Tower rock formation is constantly vibrating at this frequency, according to a University of Utah study. This is due to latent energy travelling through the Earth, and could help protect the formation from earthquakes.

ZOOLOGY

Songbirds consciously control their calls

It seems that there's order in the apparent chaos of birdsong. A new study shows that crows turn their calls on and off at will, rather than just involuntarily reacting to events going on around them.

Songbirds such as the crows are well known for their songs, which they use to attract mates, defend territory, recognise other birds, and a whole host of other social functions.

However, it wasn't known whether songbirds deliberately control their calls, or whether they are react in an emotional, 'knee-jerk' way to changes in their surroundings, such as mates, predators, or the presence of food.

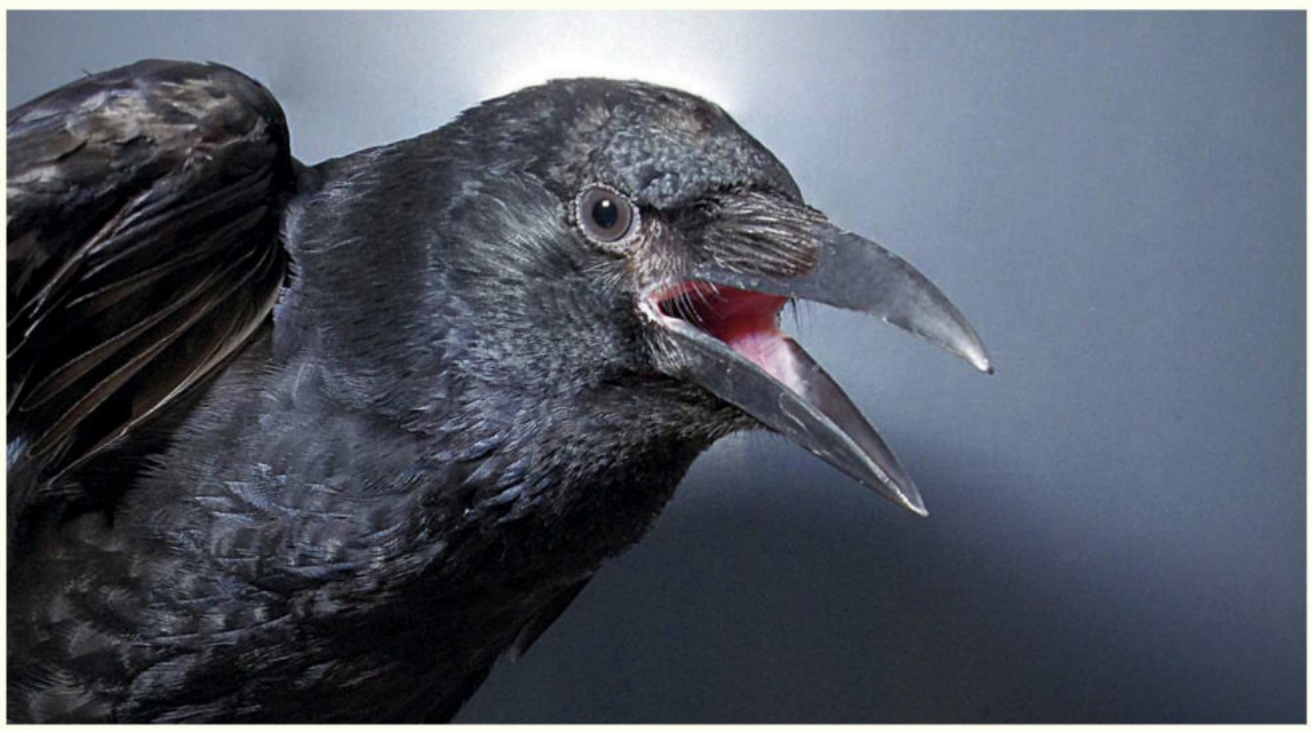
Dr Katharina Brecht and colleagues at the University of Tübingen in Germany investigated this by training three male crows to emit calls in response to a visual 'go' cue (a blue square) and to withhold their calls in response to another cue (white square).

In a second experiment, two of the crows were trained on a similar task with the colours of the squares reversed, as well as being trained to withhold their calls to another 'no go' cue (turquoise square).

The researchers found that the crows produced precise and reliable calls in the 'go' trials, and that they quickly learnt to suppress their calls in the 'no go' trials.

"Our study shows that crows can be taught to control their vocalisations, just like primates can, and that their vocalisations are not just a reflexive response," said the authors. "This finding not only demonstrates once again the cognitive sophistication of the birds of the crow family, it also advances our understanding of the evolution of vocal control."

"Crows can be taught to control their vocalisations"



Despite their rather tuneless cawing, crows are classified as songbirds

EMOJI USERS

Perhaps it's time to whack a few smileys in your dating profile. Daters that make heavy use of emojis hook up more often and have sex more regularly, a study at the Kinsey Institute has found. It may be because they are better at communicating desire.

CAT LOVERS

The stereotypical 'crazy cat lady' is a myth, a study carried out at the University of California has found. Their survey of 561 Californians found that those with cats were no more likely to be lonely, anxious, or have difficulty forming relationships than owners of other pets or those without pets.

Good month

Bad month

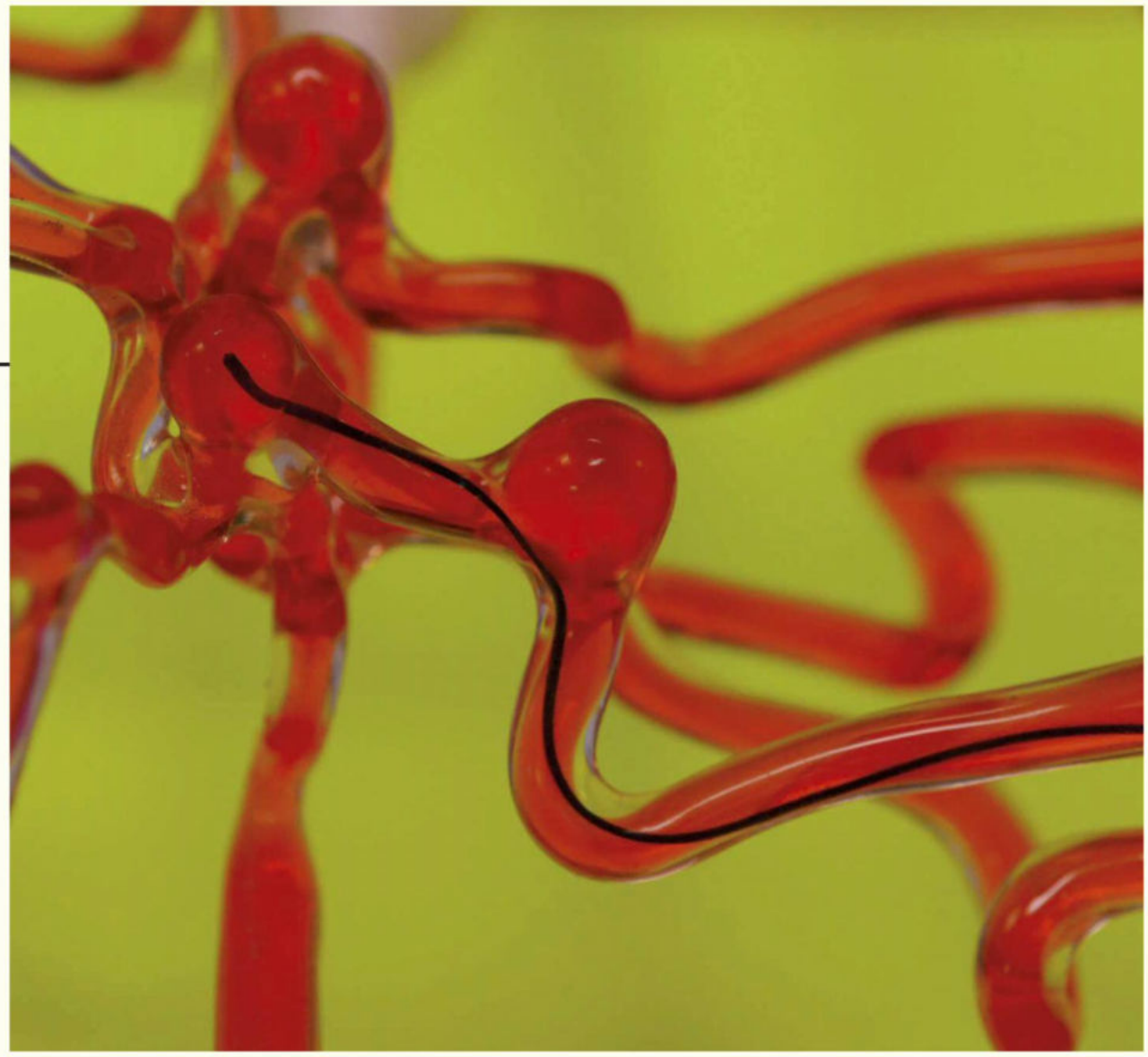
ATHLETES

Though they may go to great lengths to keep themselves in tip top condition, there is one area of athlete's bodies that are often in poor shape: their teeth. A study carried out at UCL has found that almost half of athletes have untreated tooth decay. Sugary sports drinks, energy bars and gels are most likely to blame, they say.

ARACHNOPHOBES

If the mere mention of the word 'spider' sends you into hysterics, it's probably best that you avoid storm-prone regions. Spiders born in areas with high incidence of hurricanes are more aggressive than those born in calmer environments, researchers at McMaster University have found.

GETTY IMAGES, TOBIAS MACHTS, MIT ILLUSTRATIONS: GABRIEL SILVERA



The robot was guided through replicas of blood vessels without causing damage

NEUROSCIENCE

Flexible robot slides through blood vessels in the brain

A thread-like robot steered by magnets could treat blood clots in stroke patients to prevent brain damage. The flexible robot was designed by researchers at MIT to slide through the brain's blood vessels without getting stuck.

The team hopes that the bot will replace the traditional method of treating blockages and lesions, which currently involves a surgeon inserting a thin wire into a major blood vessel in the patient's leg or groin and directing it into the brain by hand. Not only is this process difficult, but any wrong moves can cause further damage. It is also potentially harmful to the surgeon, because a real-time X-ray (known as fluoroscopy) is used to pinpoint the wire's location in the blood vessel, therefore exposing them to repeated doses of radiation.

"Stroke is the number five cause of death and a leading cause of disability in the United States. If acute stroke can be treated within the first 90 minutes or so, patients' survival rates could increase significantly," explained associate professor Xuanhe Zhao, who took part in the research. "If we could design a device to reverse blood vessel blockage within this 'golden hour', we could potentially avoid permanent brain damage. That's our hope."

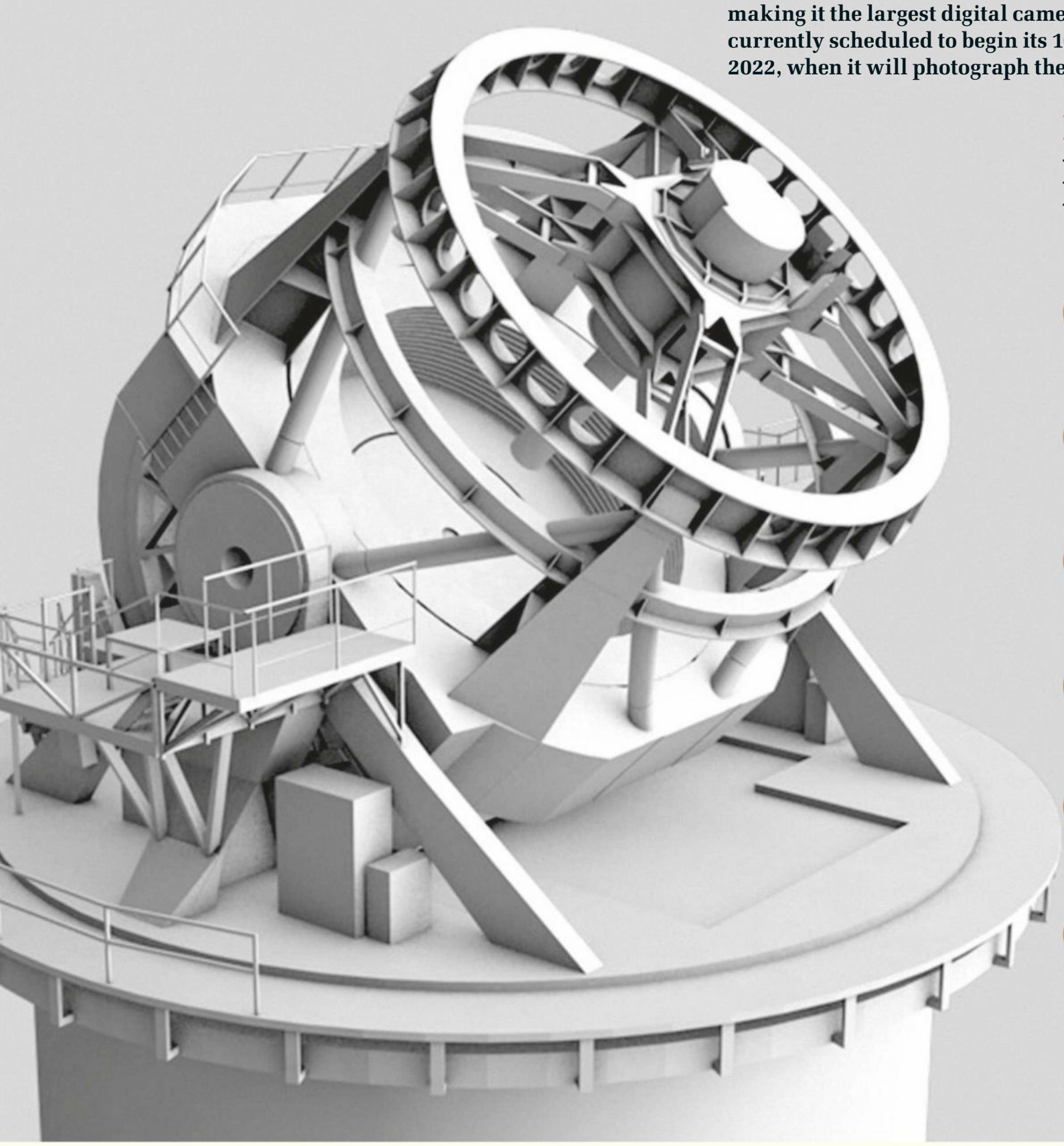
The robot thread has a thin wire core made of a springy nickel-titanium alloy, coated in a rubbery 'ink' that's embedded with magnetic particles. Around the core is a layer of a 'hydrogel', a soft, non-toxic, water-based material that gives the robot a smooth surface to reduce the chance of it damaging blood vessels or getting stuck.

Currently, the robot is controlled by hand: the team have tested it in a silicone model of a stroke patient's brain, directing the robot thread by moving a magnet around the outside of the model. However, in the future, the surgeon could control the magnets from outside the operating room, or even from a different location.

Data crunch

ASTRONOMY'S BIG PICTURE

At the summit of Cerro Pachón mountain in northern Chile, work is underway to build what will be one of the biggest optical telescopes ever created – the Large Synoptic Survey Telescope. After 16 years' of planning, scientists at Brookhaven National Laboratory recently completed the telescope's 3.2 gigapixel sensor array, effectively making it the largest digital camera ever built. The telescope is currently scheduled to begin its 10-year survey in January 2022, when it will photograph the entire sky every few nights.



LSST in numbers

THIS TELESCOPE WILL PRODUCE THE DEEPEST, WIDEST IMAGES OF THE UNIVERSE TO DATE

8.3 The size of LSST's mirror (in metres); the width of a singles tennis court

3,200 The number of megapixels in its digital camera, the largest ever created

37bn The number of stars and galaxies that will be studied during the project

10yrs The duration of the LSST's operational period, concluding in around 2033

10m The rough number of alerts each night showing astronomical changes

20TB The colossal amount of data generated by the LSST over a single night

INFOGRAPHIC BY JAMES ROUND

Objectives

Cataloguing the Solar System

The LSST is the latest in a long line of efforts to catalogue the Solar System, starting with Persian astronomer Abd al-Rahman al-Sufi's *Book Of Fixed Stars,* which was written in 964 AD. The LSST is one of the biggest optical telescopes ever created and imaging the night sky in order to catalogue it will take up 90 per cent of the telescope's time.

Exploring the changing sky

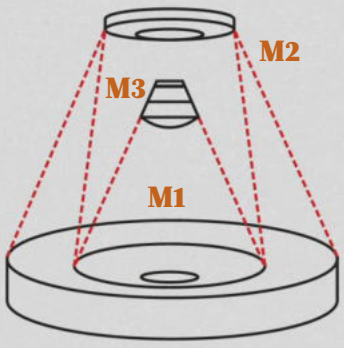
As it will be producing 200,000 images a year, taken at set locations at different times, the LSST is ideally placed to spot 'transient' phenomena such as supernovae and gamma-ray bursts. Boasting far greater image resolution than other telescopes, it is also expected to identify thousands of new objects in the Kuiper Belt beyond Neptune.

Milky Way formation

Because the LSST will produce clear images of more, smaller objects than ever before, it will help scientists produce the most complete 3D map of the Milky Way to date. This will shed new light on how the Milky Way was formed – which, as the Milky Way is a fairly typical spiral galaxy, will teach us more about galaxy formation generally.

Dark matter and dark energy

By mapping galaxies through time and space, while cataloguing their masses, it is hoped the LSST will be able to provide more clues as to the nature of the mysterious dark matter and dark energy. Scientists hope, in particular, to learn more about how dark matter affects the shape of galaxies when they first begin to form.



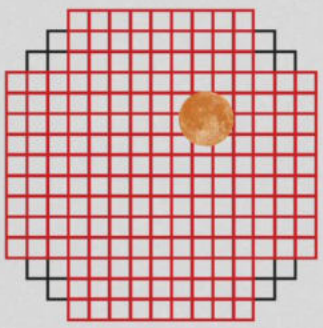
Anatomy

Mirrors

The Large Synoptic Survey Telescope uses a three-mirror system, based on a type of telescope known as a 'Paul-Baker three-mirror anastigmat'. Three-mirror telescopes aren't subject to as much visual distortion as one- and two-mirror 'scopes. In the case of the LSST, mirrors 1 and 3 are actually made from a single piece of glass, which reduces the telescope's overall length.

Field of view

The LSST will be able to provide sharp images of an area of sky measuring 3.5° across. For comparison the Sun and Moon each measure roughly 0.5° across as seen from Earth, while the field of view of a typical domestic telescope, as used by amateur astronomers to observe the night sky, is less than 1°. By providing high-quality images with such a broad field of view, the LSST will enable astronomers to piece together a more complete picture of the stars above than ever before.



Camera

The LSST will capture around 200,000 images of the sky every year. It will do this using a 3.2-gigapixel camera that captures a 15-second exposure every 20 seconds. The camera, which is believed to feature the biggest sensor ever built, is being constructed by the SLAC National Accelerator Laboratory, who will make use of the LSST as part of their hunt for dark matter.

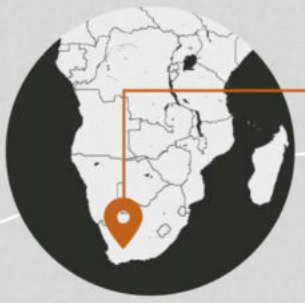
Other large telescopes

Extremely Large Telescope
CHILE / OPERATIONAL 2025

This five-mirror anastigmat, operated by the European Southern Observatory and located in Chile's Atacama desert, will be the largest optical/infrared 'scope in the world, boasting a 39.3m primary mirror. measures a whopping 393m across.

500m Aperture Spherical Telescope
CHINA / OPERATIONAL 2016

Known as FAST for short, this radio telescope sits in a natural basin and has a dish antenna measuring 500m across, making it the largest filled-aperture radio telescope in the world.

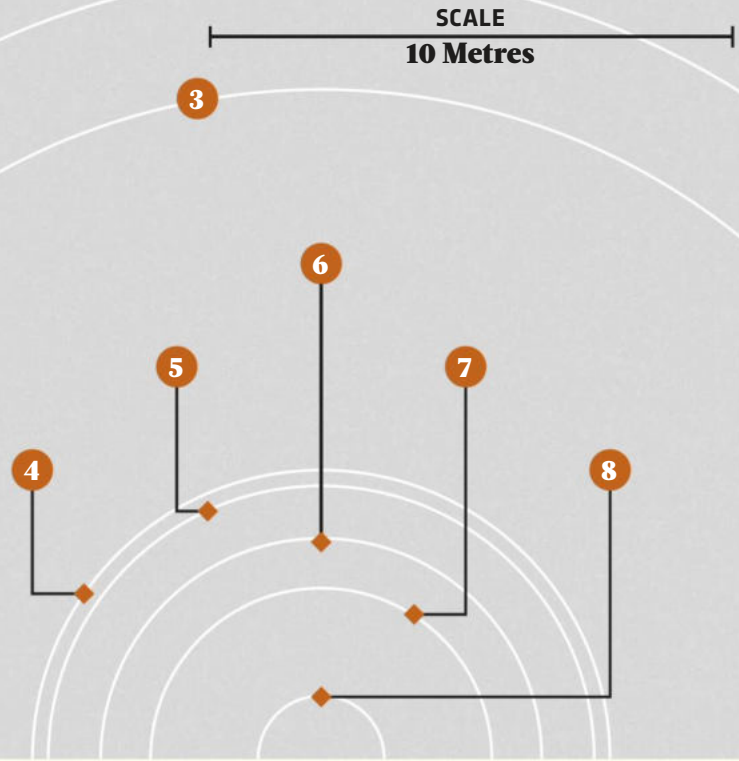


SALT
SOUTH AFRICA / OPERATIONAL 2005

This 11m optical telescope has a primary made up 91 hexagonal segments, each with a diameter of 1m. It is located inside a nature reservation, some 270km (230 miles) northeast of Cape Town.

Comparison of sensor sizes

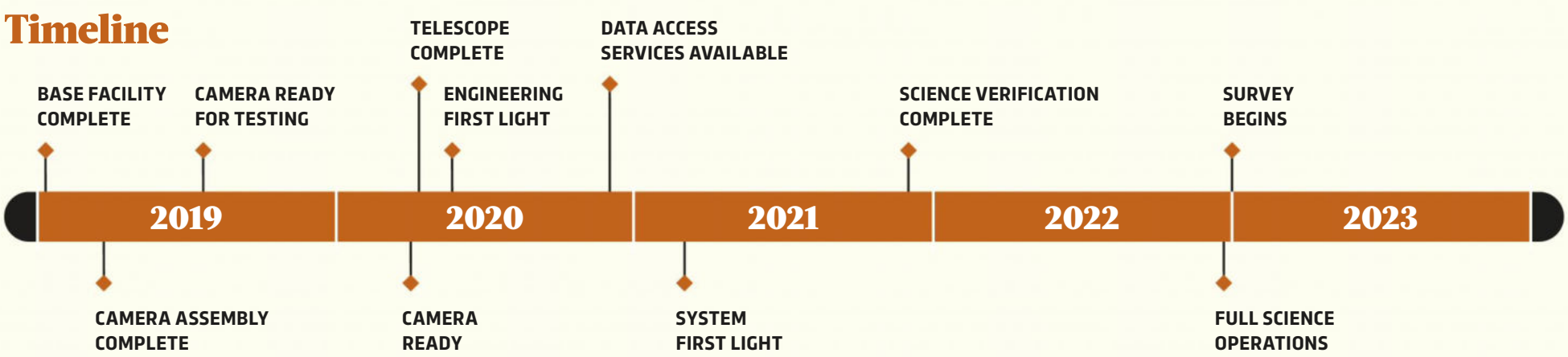
When it comes to telescopes, size really does matter – the bigger the primary mirror, the better.



1. **Extremely Large Telescope** ◆ CHILE / DIAMETER 39.3M
2. **Thirty Meter Telescope** ◆ HAWAII / DIAMETER 30M
3. **Giant Magellan Telescope** ◆ CHILE / DIAMETER 25.4M
4. **SALT** ◆ SOUTH AFRICA / DIAMETER 11M
5. **Gran Telescopio Canarias** SPAIN / DIAMETER 10.4M
6. **LSST** ◆ CHILE / DIAMETER 8.4M
7. **James Webb Space Telescope** IN ORBIT / DIAMETER 6.5M
8. **Hubble Space Telescope** IN ORBIT / DIAMETER 2.4M

◆ Symbol denotes that the telescope is not yet in full science operation.

Timeline



GREEN PAPERS

The environmental stories you need to know

Highly contentious fracking site in Lancashire

INDIA'S PLASTIC BAN

India is set to ban six single-use plastic items, including bags, cups and straws, say officials. The nationwide ban will come into place on 2 October, the birth anniversary of independence leader Mahatma Gandhi. Plates, small bottles and some sachets will also be covered, officials told Reuters. If properly enforced, the measure is expected to cut 5 to 10 per cent from the country's plastic consumption. Indian prime minister Narendra Modi had previously urged people to "take the first big step" towards freeing India of single-use plastic. "On this 2 October, can we make India free from single-use plastic?" he said during his Independence Day speech on 15 August.

ENERGY

Capacity of shale gas to meet energy needs is lower than expected

Shale gas advocates in the UK may be feeling despondent this month

Resources of UK shale gas could be just one-sixth of what was previously thought, according to estimates from the University of Nottingham and the British Geological Survey (BGS).

In a study published in *Nature Communications*, researchers looked at the amount of gas in the Bowland Shale, which is an area stretching from Lancashire down into the Midlands, and is viewed as the country's largest and most economically viable shale resource. The new estimates, derived from data taken from UK shales,

BANANA WOES

Banana farmers in some of the world's biggest producing countries could be hit hard by climate change. The changing climate has made conditions more favourable for bananas in recent decades, according to research published in *Nature Climate Change*. But these gains could disappear by 2050 if climate change continues at its expected rate, the study found. Ten major banana exporters could be negatively affected, including India, the world's biggest producer. The impacts of climate change on bananas have been largely ignored so far, said study co-author Daniel Bebbe. "There will be winners and losers in coming years."

predicted supply could actually amount to less than 10 years' worth. This is in contrast to an earlier 2013 BGS study that found Bowland shale could meet current gas demand for up to 50 years.

The new findings will help to improve people's understanding and government decisions on the future role of shale gas in the UK's energy demand, as the country moves towards carbon neutrality by 2050, said study co-author Prof Colin Snape.

But the authors were keen to stress there is still a large degree of uncertainty in all shale estimates. A "truly foolproof" assessment can only come from widespread test drilling, they say.

"To be honest, I wasn't surprised at all," said Darrick Evensen, a lecturer in environmental politics at the University of Edinburgh.

The downward revision follows a similar trend seen in the US.

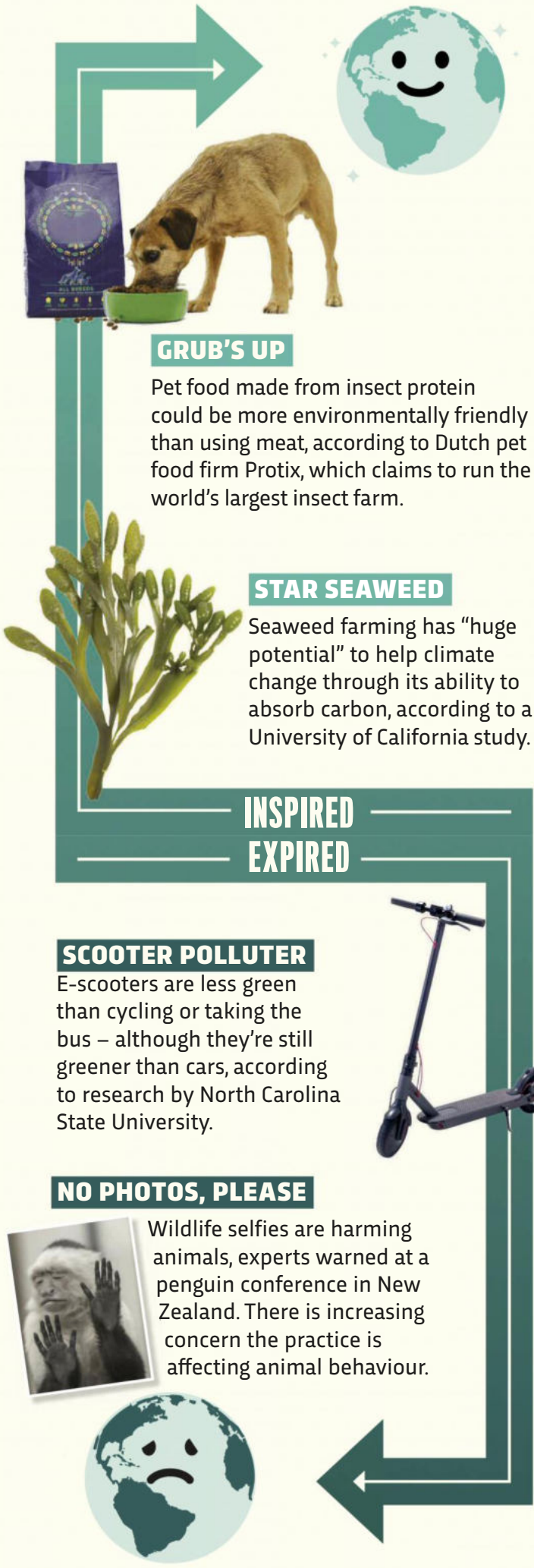
"Initial estimates come out, and there's only one direction they ever go from there: they always go down"

"Initial estimates come out, and there's only one direction they ever go from there: they always go down. It's not bad science, it's what they have available at the time to do the estimates," Evensen said.

Here in the UK, the government argues that shale gas could be an important new domestic energy source. It recently indicated it may be willing to rethink its rules on the tremors caused by fracking for shale, which have stunted the industry.

Polls of the general public have long shown that opposition to fracking is far higher than support. In the latest survey, opposition sat at 35 per cent, compared to 15 per cent support. Such 'above ground factors' are actually likely to determine if and how the UK ends up using any shale gas resources, said Laurence Williams, a research fellow in environmental politics from the University of Sussex, who studies the public perceptions of fracking.

"That would be things like government policy, public attitudes, but also some stuff in terms of the relationship between shale gas and climate change and whether that is reconcilable," he said.



GRUB'S UP

Pet food made from insect protein could be more environmentally friendly than using meat, according to Dutch pet food firm Protix, which claims to run the world's largest insect farm.

STAR SEAWEED

Seaweed farming has "huge potential" to help climate change through its ability to absorb carbon, according to a University of California study.

INSPIRED EXPIRED

SCOOTER POLLUTER

E-scooters are less green than cycling or taking the bus – although they're still greener than cars, according to research by North Carolina State University.

NO PHOTOS, PLEASE

Wildlife selfies are harming animals, experts warned at a penguin conference in New Zealand. There is increasing concern the practice is affecting animal behaviour.

GETTY IMAGES X5

IT IS EASY BEING GREEN

REUSE AND RECYCLE OLD GADGETS

As many as 40 million electronic devices are sitting unused in drawers in the UK, according to research by Ipsos MORI for the Royal Society. These old gadgets are often hoarded in our homes, yet they contain rare metals that could run out in the next 100 years and are needed for green technologies.To help, you can hold off upgrading your phone for another year or pass your old phone to a relative, the Royal Society said. If your device is no longer usable, don't just toss it in a drawer. Instead, look up recycling options in your area at **recyclenow.com**.

SLEEPING TOO MUCH OR TOO LITTLE CAN INCREASE YOUR RISK OF HEART ATTACK

People who get less than six hours of sleep per night, or more than nine, could be at higher risk of heart disease, according to a study at the University of Colorado Boulder. Even taking into account lifestyle factors such as diet, exercise and smoking, those who got sleep within this 'Goldilocks range' were the least likely to have a heart attack over a seven-year period. Good news if heart disease runs in the family: just like having a good diet, getting your sleep habits 'just right' can also reduce your risk of a heart attack.

BRAIN

The secrets of strong memories decoded

Why is it that you can remember the names of childhood friends that you haven't seen in years, yet easily forget the name of someone you just met a moment ago? Researchers at Caltech may have found the answer: strong, persistent memories are encoded by 'teams' of neurons all firing together to ensure that certain memories stay remembered.

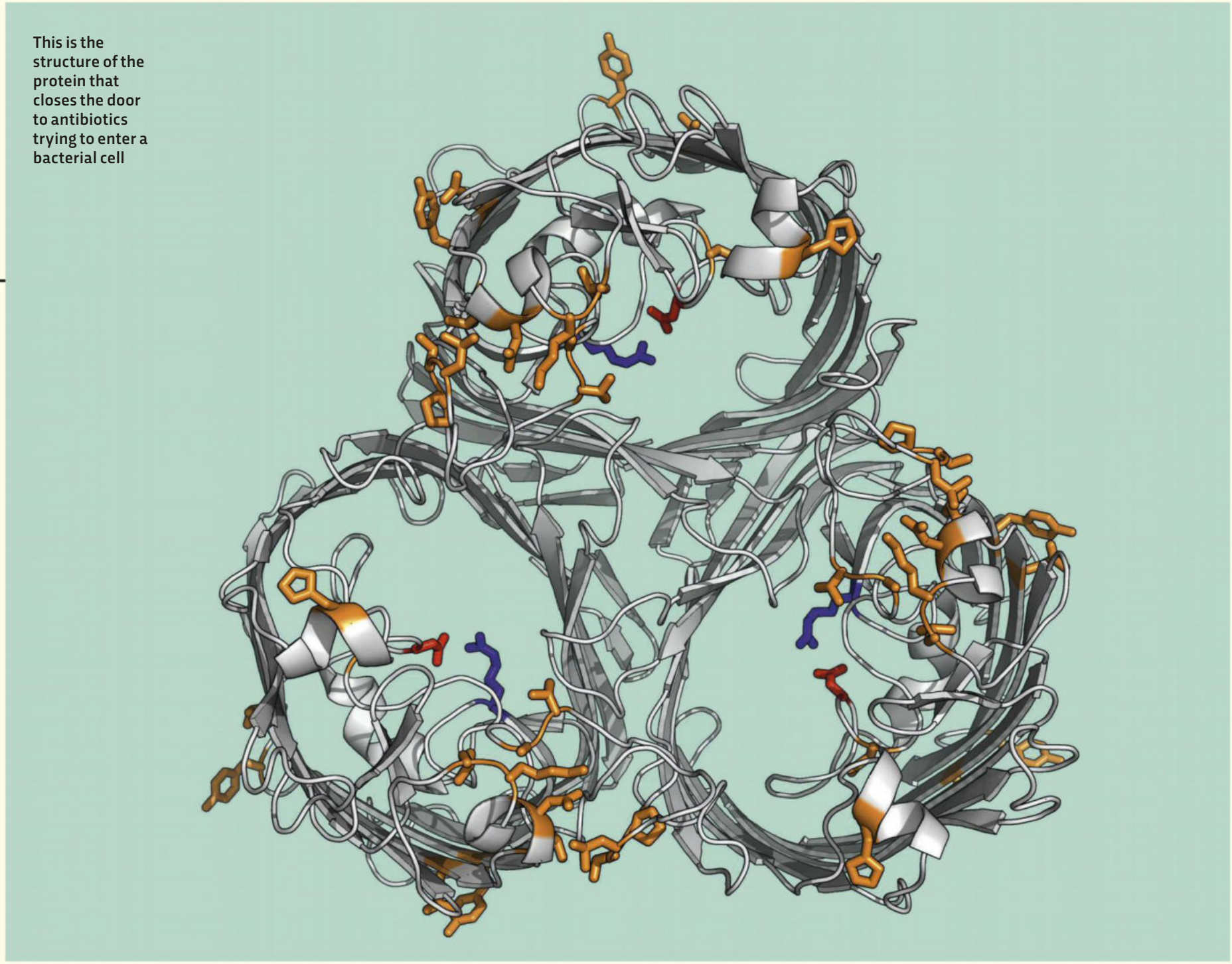
The researchers developed a test to examine the neural activity of mice as they learnt and remembered a new place. First, they placed mice one at a time in a long, white enclosure with signs marked at various locations along the walls, like a plus at one end, and a slash in the centre. Treat dispensers containing sugar water were positioned at either end. As the mice explored, the team measured the activity of specific neurons in the hippocampus – the region of the brain where new memories are formed – that are known to encode memories of places.

At first, they found that single neurons were activated when the mice spotted one of the symbols. As the mice became familiar with the track, and remembered the locations of the sugar, more and more neurons were activated whenever they spotted a symbol. Essentially, the mice were recognising where they were within the track.

A greater number of neurons, like the one visualised here, will activate when a task is repeated, therefore forming stronger memories

After a 20-day break, the researchers returned the mice to the track. Those that had formed memories encoded by a higher number of neurons remembered the task more quickly.

"For years, people have known that the more you practice an action, the better chance that you will remember it later," said Prof Carlos Lois, who led the research. "The conventional theories about memory storage postulate that making a memory more stable requires the strengthening of the connections to an individual neuron. Our results suggest that increasing the number of neurons that encode the same memory enables the memory to persist for longer."



This is the structure of the protein that closes the door to antibiotics trying to enter a bacterial cell

GETTY IMAGES X2, WONG ET AL.

MEDICINE

Scientists discover how bacteria block out antibiotics

New 'lock-picking' drugs could get inside the bacterial cells and help us beat antibiotic resistance

Drug-resistant bacteria responsible for deadly infections that spread inside hospitals have been on the rise for several years. Over time these bacteria have developed the ability to shut out antibiotics by closing tiny doors in their cell walls, rendering them ineffective.

However, things may be about change. Researchers at Imperial College London have discovered how bacteria lock out antibiotics, highlighting a new avenue to tackle antibiotic resistance.

The team concentrated their efforts on *Klebsiella pneumoniae* – a bacterium that causes infections in the lungs, blood, and open wounds. Like many bacteria, *K. pneumoniae* is becoming increasingly resistant to antibiotics, particularly a group of drugs called carbapenems. These are a class of antibiotics that are used when others have failed.

Antibiotics usually enter the *K. pneumoniae* bacteria through surface doorways known as pores. However, the scientists found that antibiotic-resistant *K. pneumoniae* have modified versions of the proteins necessary to fully form these pores, leading to cell walls that antibiotics are unable to penetrate. Finding a drug that could reverse this process, and reopen the pores, is one way to combat antibiotic resistance in *K. pneumoniae*.

"The modification the bacteria use to avoid antibiotics is difficult to get around. Any drugs to counteract this defence mechanism would likely also get blocked out by the closed doors," said research leader Prof Gad Frankel. "However, we hope that it will be possible to design drugs that can pick the lock of the door, and our data provides information to help scientists and pharmaceutical companies make these new agents a reality."

Dr Ben Sessa psychiatrist

Horizons

MDMA therapy shows promise in treating alcohol misuse

Preliminary study indicates that the drug outperforms conventional therapies in preventing relapse

HOW DID THE RESEARCH COME ABOUT?

As a psychiatrist working with children and adolescents, I spent years working with abused and maltreated children. Then I moved into adult addictions, and realised that adults in their 30s, 40s and 50s with cocaine, opiate and alcohol addictions are the same cohort of grown-up children. Almost all have experienced childhood trauma.

I knew MDMA therapy was being used to treat PTSD successfully, and I saw adult addictions as 'PTSD plus drug'. Alcohol misuse is a major public health concern in this country. The obvious thing to do, in my opinion, was an MDMA therapy study for alcohol use disorder. We got independent funding from a philanthropist donor, and we were away.

WHAT HAPPENS IN A TYPICAL TREATMENT PROGRAMME?

First, patients undergo medical detox, then in the first week of finishing the detox they enter an eight-week course of weekly psychotherapy sessions – most of them non-drug sessions. On weeks three and six, interspersed with non-drug sessions, they have an MDMA-assisted psychotherapy session. The session lasts all day and then they stay in the facility overnight before being seen again the next day.

WHAT DOSE OF THE DRUG ARE THE PATIENTS GIVEN?

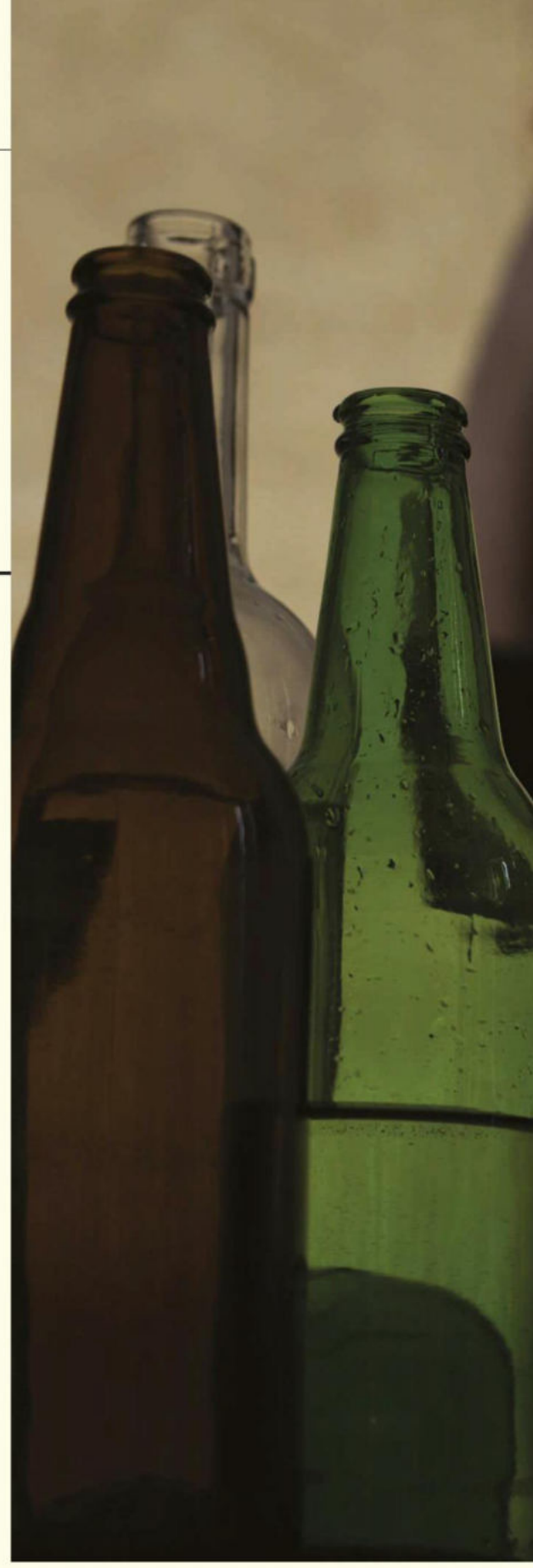
Initially 125mg, then a further 62.5mg two hours later. They do this on two occasions, during weeks three and six of the course.

HOW DOES THE MDMA HELP WITH THE THERAPY SESSIONS?

MDMA reduces the fear response. This allows for safe recall of traumatic memories that the patient would normally avoid. This allows them to fully engage in psychotherapy, and to reflect upon, challenge and eventually resolve past traumas.

HOW SAFE IS THE TREATMENT?

The dangers are very low indeed. We're not talking about ecstasy tablets, we're talking about clinical MDMA. This is not like taking it in a nightclub where you don't even know what you're taking. They're in a hospital setting with a doctor, a nurse, a therapist. We monitor their blood pressure, heart rate and temperaturae every half hour. They stay all day, then they sleep over in the therapy centre and we see them the next morning. We telephone them every day for a week, and then we see them every week for 10 weeks, then we continue to follow them for up to nine months. They have blood tests and ECGs before and after the treatment. The risks are reduced to an absolute



GETTY IMAGES

"MDMA reduces the fear response. This allows for safe recall of traumatic memories the patient would normally avoid"

minimum. It's actually a remarkably safe drug, much safer than, for instance, the psychiatric medications I prescribe to people on a daily basis.

WHAT SORT OF SUCCESS RATE HAVE YOU HAD WITH THE TREATMENT?

Well, firstly, this is an open-label pilot study. There's no control group, there's no placebo. So we can't really make inferences about treating alcoholism, because it might not be the drug at all – it might just be the wonderful therapist! You can't make a formal, scientific statement about that. It's primarily a safety intolerability study. We're basically looking at whether or not the drug is safe and can be tolerated. And they tick all the boxes in that way. The patients are tolerating it completely, and there have been no adverse reactions or physiological problems at all. So, that's the main purpose of the study.

Now, of course, we can look at the data. We have 12 people in the study at the moment. Two have relapsed back to the levels of drinking they came in with, five are completely dry, and then there's about another five who have had one or two drinks, but not gone back to the full level of drinking – they wouldn't satisfy the diagnosis of alcohol use disorder. By that rate, we've got 10 people cured and two returned to alcohol use. If you compare that to the current best treatment which is rehab, detox rehab, AA [Alcoholics Anonymous], group therapy, individual therapy and so on, it completely blows that out of the water. With current treatment, after nine months about 70 per cent of people are back to full drinking again.

So we can't really say anything formally, as I said. But the people who have been on the study have certainly done really well compared to people who haven't.

COULD THE SAME METHOD ALSO BE USED TO TREAT OTHER ADDICTIONS AND CONDITIONS?

Yes. In many ways MDMA can be seen as a non-specific adjunct to psychotherapy. Most addictions, probably except nicotine, are trauma-based. MDMA is an excellent tool to assist trauma-focused psychotherapy.

WHAT NEXT STEPS DO YOU HAVE PLANNED FOR THE RESEARCH?

We now plan to carry out a randomised controlled study, using a placebo group alongside an active MDMA group, in order to test the efficacy of MDMA-assisted psychotherapy.

Recreational MDMA and ecstasy are illegal Class A drugs. Possession can get you up to seven years in prison; supplying can get you life imprisonment. For information and support, visit ***bit.ly/drug_info***

DR BEN SESSA

Ben is an adolescent and adult addictions psychiatrist at Imperial College London and the University of Bristol. ***Interviewed by*** **BBC Science Focus** ***commissioning editor Jason Goodyer.***

Afar, Ethiopia

PALAEONTOLOGY

Fossilised skull reveals face of early human

The skull belonged to the oldest-known member of *Australopithecus* – a group of east African hominins that preceded the emergence of the *Homo* genus by around two million years

The skull was discovered in 2016 at Miro Dora, in the Mille district of the Afar Regional State in Ethiopia. Analysis of its shape indicates that it belongs to *Australopithecus anamensis*, an ancient hominin that dates back to a time when early human ancestors were transitioning from living in trees to living on the ground. The structure of its leg bones and ankle joints indicates that they walked upright on two feet, but their long arms and wrist bones also suggests that they were accomplished climbers. The size of the skull's cranial cavity indicates that its brain was about the same size as a chimpanzee's.

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2

3

1. The researchers used distinctive features of the skull, particularly those of the upper jaw and canine teeth, to determine that it belonged to a representative of *Australopithecus anamensis*, a hominin species that lived between 4.2 and 3.8 million years ago. The term 'hominin' refers to any human-like ape species, including modern humans as well as all of our early ancestors.

2. The age of the fossil was determined as being around 3.8 million years old. To deduce this, sedimentologist Beverly Saylor and her colleagues at Case Western Reserve University in Ohio dated the minerals in layers of volcanic rock found nearby.

3. Palaeoartist John Gurche, who is artist-in-residence at New York's Museum of the Earth, used the skull to piece together an incredibly realistic facial reconstruction of *A. anamensis*.

4. The skull was displayed alongside a 3D-printed replica during a press conference in Addis Ababa hosted by Ethiopian palaeoanthropologist Prof Yohannes Haile-Selassie, who found the skull.

4

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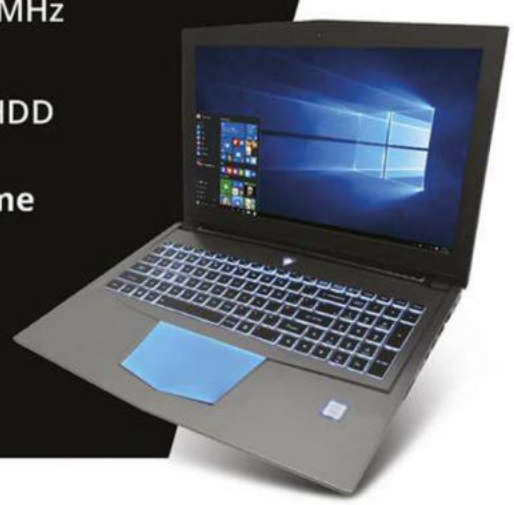

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Amazon rainforest | The hygiene hypothesis | Carbon offsetting

ANALYSIS

THE AMAZON RAINFOREST: COULD IT BECOME A DESERT?

Fire consumed the outskirts of the Amazon rainforest in August. With mortality rates of tropical trees increasing, we ask: could the ecosystem be tipped into a barren desert environment?

“If deforestation increases, it could change the climate in the rainforest to one that is less favourable to tropical tree species”

LEFT A farmer walks through burnt area of the rainforest in Brazil

RIGHT An area of the Brazilian Amazon that was decimated by fires in August this year

News of fires in the Amazon rainforest spread around the globe in August, as huge areas were set alight to clear the land for machine farming. The figures that emerged shocked the planet: there had been nearly 50,000 fires in Brazil in the first eight months of this year, up 84 per cent from the same period in 2018. If this trend continues, the whole rainforest ecosystem could be at risk.

The Amazon rainforest is not equipped to deal with fire. Unlike other ecosystems, such as the African savannah, where wildfires are common, the rainforest is too wet to ever catch alight naturally. Any fire started there has been ignited by human activity.

Not all fires in the Amazon are illegal, however. In some states, land owners are able to apply for a licence to deforest up to 20 per cent of their property, in order to clear areas to build on, farm or mine. To do this, trees are felled and laid out under the hot sunshine. After a number of weeks, they are dry enough to burn. But this year, many states have had a ‘fire ban’ to prevent this method of deforestation. The Amazonas state in Brazil had such a ban, yet fires have still been recorded there.

Dr Adriane Esquivel-Muelbert is an ecologist at the University of Birmingham, studying the effects of climate change on forests, particularly in Brazil, her home country. Previously, her main concern was the increasing number of widespread droughts, which kill millions of trees and threaten the biodiversity of the rainforest.

DESERT STORM

At the time of writing, Brazil’s National Institute for Space Research (INPE) has recorded 197,386 fires in South America so far this year. Half of these were in the Amazon rainforest. Esquivel-Muelbert says fire is used as it clears the land completely, flattening it to allow for the big machines that will be used by farmers. “The forest recovers from a drought after a few years, even though the types of trees there might not be the same. Whereas fire is complete destruction,” she says.

It’s a vicious cycle. As more trees die, the surrounding areas become even hotter and drier. “At the moment, the rainforest has this closed canopy that shades and protects trees,” explains Esquivel-Muelbert. “Once you take that away, it opens the canopy, and you have more space in the rainforest and more of the hot, tropical sunlight pouring in.”

As the cycle continues, the state of the Amazon as a rainforest could become threatened. Some have said that we are nearing a ‘tipping point’, at which the rainforest will irreversibly become a desert – a process that’s been dubbed ‘desertification’ by some media. The reality is closer to a ‘savannahfication’, says Esquivel-Muelbert. “If this deforestation increases, it could change the climate in the rainforest to one that is less favourable to the tropical tree species, and more favourable to ones like those found in a savannah,” says Esquivel-Muelbert. “At the tipping point, the Amazon shifts to the state of a savannah. It’s a point of no return.”

Not only would this be a huge loss of plant and animal biodiversity, but a savannah is a less effective carbon sink than the rainforest. The tipping point is a hypothesis, explains Esquivel-Muelbert, but researchers have seen indications that it could be happening. “We have seen a ➤

GETTY IMAGES X 2

shift in species there. Droughts increase the mortality of those trees that prefer rainforest conditions, while the more drought-tolerant species become favoured by the new climate."

How close are we to a tipping point? Unfortunately, it's hard for scientists to predict. "It depends on how much we preserve the forest," says Esquivel-Muelbert. "We need to act now to prevent high mortality rates and try to reverse this trajectory."

The state of the Amazon rainforest is a concern for the world, says Dr Shanan Peters, a geoscientist at the University of Wisconsin-Madison. Not just because of the oxygen it produces, but because of the carbon dioxide it locks up. "To say the Amazon is the 'lungs of the planet' is kind of a misleading statement," says Peters. "We could burn every living thing on Earth – all the trees, all the grass – and still not run out of oxygen for many, many generations of humans, but we would be devastated by the doubling of CO_2 that would happen instantly. The story of what's happening right now in the rainforest is, in my view, articulated by the impact it's going to have on CO_2. [The Amazonia fires] are exacerbating our climate crisis."

"For me, [this year's fires] are clearly linked to the rhetoric of the president," says Esquivel-Muelbert, commenting on the environmental policies of Brazil's President Jair Bolsonaro, which have been accused of failing to protect the rainforest. "But also, in a way, everyone is responsible. The actions we carry out here in the UK affect the Amazon. We have to realise the things we consume might come from farms in the Amazon… the global community needs to realise that everyone needs to help to preserve the rainforest we have remaining."

by **AMY BARRETT**, with thanks to **ERIKA BERENGUER**

Amy is editorial assistant at BBC Science Focus. *Erika is a senior research associate at the Ecosystems Lab at the University of Oxford.*

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REVIEW

HYGIENE: IS THERE SUCH THING AS 'TOO CLEAN'?

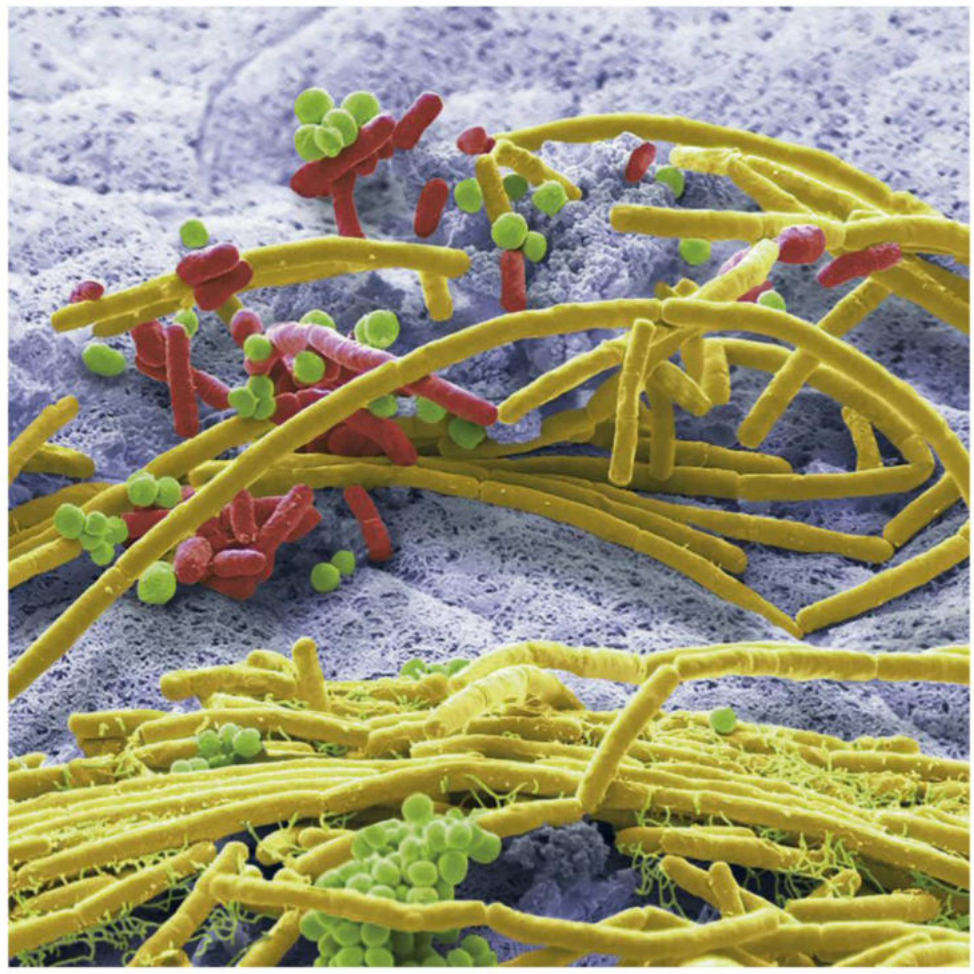
Some people choose not to wash with soap, saying our modern, sanitary lives cause allergies, damage our immune system and even upset our microbiome. But can cleanliness really be a bad thing?

Why would some people choose not to wash?

Our skin is covered in more than 1,000 types of bacteria, plus viruses, fungi and mites. Don't go bathing in antibacterial hand gel, though: most of these are harmless, and some are beneficial to us. This ecosystem is called the 'skin microbiome', and can actually protect us from illness. The bacterium *Pseudomonas aeruginosa*, for instance, produces pseudomonic acid, which protects us from staphylococcal and streptococcal infections.

LEFT Getting 'dirty' exposes children to helpful bacteria that can fight allergies

BELOW Bacteria taken from a human fingertip



More noticeably, the skin microbiome regulates the way we smell. Sweat itself doesn't smell: the odour filling a packed tube train comes from the bacteria that break the sweat down.

So why do some people stink? That depends on the exact population of microbes that live on your skin, since different bacteria break the sweat molecules down into different components. In fact, microbiologist Dr Chris Callewaert, also known as Dr Armpit, has shown that an underarm bacterial transplant from the fresh-smelling to the stinky can eliminate body odour.

Clearly, then, the microorganisms living on our skin can provide a service that soap and daily showers sometimes can't. So some people choose to avoid bathing – apart from hand-washing and cleaning off dirt – and let the bacteria do the work instead. The idea is that frequent use of soap products damages the skin microbiome, and we'd be better off if we just let it be. The soap-free often report that, if you can push through the inevitable smelly period when you haven't showered in a week, you will eventually stop smelling.

"Microbiologist Dr Chris Callewaert, also known as Dr Armpit, has shown that an underarm bacterial transplant from the fresh-smelling to the stinky can eliminate body odour"

—

What can you do instead of washing?

Chemical engineer David Whitlock hasn't showered in 15 years, and instead tops up his microbiome with ammonia-oxidising bacteria (AOB). Drawing inspiration from horses rolling in the dirt, Whitlock harvested AOB from soil and tested it on himself, which reportedly stopped him from smelling. He is now the founder of AOBiome, which sells a range of toiletries containing AOB. The company claims their products, sold under the name Mother Dirt, will "bring harmony and balance back to your skin microbiome". ◉

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Is there such a thing as 'too clean'?

Rates of allergies such as hay fever and asthma have been increasing since the Industrial Revolution. In 1989, epidemiologist Prof David Strachan suggested a possible reason for this: children were contracting fewer infections. He proposed that infections at an early age equipped the immune system to deal with allergens such as pollen. So the general increase in cleanliness deprived children of infections that protected them against allergic diseases.

This idea, known as the hygiene hypothesis, quickly took hold. "That gave rise to this idea that we are too clean for our own good," says Dr Sally Bloomfield, honorary professor at the London School of Hygiene and Tropical Medicine. It's a commonly mistaken view that growing up in our ultra-sterile homes causes allergies.

To say that we're currently too clean is an oversimplification. "I think that's a complete red herring," says Bloomfield. "We don't need exposure to harmful germs to prevent allergies; we need exposure to beneficial germs." Besides, as hygienic as we are, we can never make ourselves sterile. It's not the number of microorganisms, but the type.

"It's perfectly fine for kids to get muddy in the garden – most of the microbes found in garden soil will be harmless anyway"

Our skin microbiome needs a wide range of species, but we can do very nicely without the harmful ones. Due to various lifestyle changes, we have gradually lost touch with our 'old friends', the microbes that co-evolved with humans and were present even in early hunter-gatherers. These are the ones that help us to

ABOVE Bacteria in the human armpit

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develop a strong immune system, and in turn stop it overreacting to allergens. If we can get back these old friends, then we can quite contentedly wash away the pathogens, most of which evolved in the last 10,000 years, without doing us any harm.

How can you get in touch with 'old friends'?

Earlier this year, a study published in the *Journal Of Investigative Dermatology* found that a child's skin microbiome is most closely related to their mother's, and there was a noticeable difference between vaginal births and Caesarean sections. Most likely, a baby picks up their skin microbiome during the birth, adopting these old friends from their mother's vaginal microbiome.

"The way we've lost exposure to beneficial germs is not through household cleanliness, it's through lifestyle changes such as C-section childbirth rather than natural childbirth, and bottle-feeding rather than breast-feeding," says Bloomfield. "That's a vital time when children are getting exposure to the beneficial organisms they need."

Of course, pregnant women may well have more pressing concerns than skin microbes when choosing a Caesarean section, and breastfeeding may not always be an option for mothers. So some new parents have opted for 'vaginal seeding', a process that involves swabbing a newborn with the mother's vaginal fluid straight after a C-section has taken place. However, this is not necessarily advisable: a 2018 review of the evidence described it as "unjustified and potentially unsafe".

What can you do to ensure your child develops a strong immune system?

"It's about getting a balance," says Bloomfield. "We should encourage children to interact with each other, to get dirty, and we should treat them in the right way with breastfeeding and the right diet and avoiding antibiotics if we can."

So it's perfectly fine for kids to get muddy in the garden – incidentally, most of the microbes found in garden soil will be harmless anyway. But then, when they come inside for a snack, protect them from illness by making sure they wash their hands. "What we're trying to put forward is this idea of targeted hygiene: intervening in the places and the times that matter," Bloomfield says. "We call these 'the moments for hygiene'. It's about containing that risk at the moment when it is a risk."

So if you don't want to wash most of your skin with soap products, you can still protect yourself from illness by practising targeted hygiene (see guide, right).

by SARA RIGBY
Sara is online assistant at BBC Science Focus. *She has an MPhys in mathematical physics.*

WHAT ARE THE MOMENTS FOR HYGIENE?

1. WHEN USING THE TOILET
Keep yourself clean and always, always wash your hands.

2. AFTER HANDLING RUBBISH
Remember to wash your hands after taking the bins out.

3. WHEN PREPARING FOOD
Wash your hands before touching food. Wash fruit and veg. After preparing raw meat, wash your hands and utensils straight away.

4. BEFORE EATING WITH YOUR HANDS
Hands are a big carrier of microbes, so make sure not to put harmful germs straight in your mouth.

5. AFTER COUGHING, SNEEZING OR BLOWING YOUR NOSE
Wash your hands and dispose of used tissues straight away.

6. WHEN LOOKING AFTER SOMEONE WHO'S ILL
If they're coughing, sneezing or vomiting, they're most likely still infectious.

7. AFTER HANDLING DIRTY LAUNDRY
There's a reason you're about to wash it, which means you should clean your hands after you touch it.

8. AFTER PLAYING WITH OR CARING FOR PETS
Even if your pets aren't dirty, they may still be carrying microbes which are harmful to humans.

COMMENT

CARBON OFFSETTING: A SOLUTION TO FLYING EMISSIONS, OR JUST PASSING THE BUCK?

Can we justify long-haul flights with measures to offset carbon?

Flying has been in the news a lot lately. Not because of the usual stories like delays, staff strikes or excess luggage fees, but because of a more fundamental problem: aviation's huge carbon footprint. We've recently learned of Prince Harry and Meghan's penchant for private jet travel, and Sir Elton John has raised the idea of buying offsets as a way to fly 'carbon neutral'. Elsewhere, environmentalists like Greta Thunberg and thousands of her followers are giving up flying completely. But is air travel really such a big problem?

Unfortunately it is. The aviation industry consumes five million barrels of oil every day, contributing around 2.5 per cent of global carbon emissions. If considered as a country, its carbon footprint is similar to that of Germany. The vast majority of flights are taken for leisure – around two-thirds in the UK – and just 15 per cent of passengers account for 70 per cent of flights.

And aviation is growing, fast. Thanks to growing affluence and affordable fares – helped by a long-standing zero-tax regime for international jet fuel – demand keeps rising. Passenger numbers doubled over the last 20 years, and are predicted to double again from around four billion annual journeys to 8.2 billion by 2037, according to the industry body IATA.

As things stand, air travel could account for 22 per cent of all emissions by 2050, putting huge strain on other vital sectors to decarbonise even faster. Some question whether it is fair to demand deep cuts in sectors like agriculture or energy, which are fundamental to human survival, while exempting aviation, which isn't.

Under pressure, the industry's regulatory body, the International Civil Aviation Organisation (ICAO) has come up with the Carbon Offsetting and Reduction Scheme for International Aviation, or CORSIA, to deal with the industry's carbon emissions. The scheme has two key assumptions. First, that aviation can continue to grow. Second, that there can be 'carbon-neutral growth from 2020', by making flights more efficent, and by purchasing large-scale carbon offsets. Some argue that these goals are mutually exclusive, and the scheme won't kick in fully until 2027.

"Offsetting isn't particularly effective: a recent EU study found that 85 per cent of offset projects failed to produce the promised carbon reductions"

FLYING NEUTRAL?

A few individual flyers take matters into their own hands by offsetting their flights. Offsetting means compensating for one activity that produces carbon, like a flight, by paying for another activity which removes an equal amount of carbon, like planting trees. Sir Elton John claimed that because he bought offsets for the royal couple's flight, their air travel was therefore 'carbon neutral'. However, this claim may be too good to be true, for several reasons.

Time-wise, a flight taking off today emits its carbon today. Waiting for trees to mature to the stage when they can remove that carbon takes many years – time which we may simply not have to spare. Furthermore, offsetting isn't always effective: a recent EU report concluded

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that 85 per cent of offset projects examined didn't deliver their promised carbon reductions. Incidentally, the most robust offsets involved industrial processes like capturing methane from landfill sites, rather than more 'photogenic' projects like tree-planting or installing green energy.

At a societal level, carbon offsets, either at an individual passenger level, or at a CORSIA-style industry level, may seem like a way to avoid taking responsibility for our own behaviour. So perhaps we ought to view offset schemes as a well-intentioned form of charity, not a scientifically-grounded way to be 'carbon neutral'.

INDIVIDUAL ACTION

Critics of offsetting argue that aviation demand urgently needs to be constrained, perhaps by applying a carbon tax to all flights, or a frequent flyer levy whereby passengers who fly more, pay more. Yet so far, governments and politicians are reluctant to go anywhere near a 'flying tax' – despite the huge revenues that could be generated and used to fund lower carbon transport alternatives.

The single best way to reduce one's own carbon footprint is to fly less, as a growing movement of non-flyers is finding out. I'm one of them. Having pledged to give up flying in 2019 and 2020, I've found other ways to have holidays and do international work, even travelling by train from Southampton to China to conduct fieldwork earlier this year. It took almost two weeks each way, but contributed only 10 per cent of the carbon emissions of equivalent flights.

Such individual actions often seem small, but can lead to collective change. If we want politicians to make brave choices and regulate aviation properly, then travellers can signal their support by skipping flights where possible and supporting campaigns to tax flying properly, rather than simply passing the buck by buying carbon offsets.

Planting trees may make you feel better about taking your flight, but it is an ineffective way to offset your carbon emissions

by **DR ROGER TYERS**

Roger is a post-doc research fellow at the University of Southampton, whose work focuses on consumer attitudes to green regulation of the aviation industry.

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THE TRANSPORT REVOLUTION

FROM HYPER-FAST TRAINS TO FLYING TAXIS, WE LOOK AT THE VEHICLES THAT ARE SET TO TRANSFORM HOW WE GET AROUND

WORDS: **ANDY RIDGWAY**

GOING LOOPY

↑ HYPERLOOP

There's been a lot of hype, but this sleek capsule built by California-based Hyperloop Transportation Technologies (HyperloopTT) shows that super-fast hyperloop travel is on its way, promising speeds of up to 1,223km/h (760mph) for city-to-city travel – faster than a commercial jet.

The full-scale, 30m capsule is being prepared for testing at HyperloopTT's 320m test track in Toulouse, France. If all goes well, the first passenger trials will take place next year, with the aim of having the first commercial system up and running by 2022, probably in Abu Dhabi.

Hyperloop capsules will reach their high speeds by gliding through sealed tubes from which most of the air has been removed by vacuum pumps, reducing drag. The capsules are levitated just above the track using magnets, reducing friction, and powered by a 'linear induction motor' that also uses magnetic forces.

The Hyperloop has been hailed as the first new mode of transportation in over 100 years, but there are still significant technological challenges to overcome, such as the complexity of maintaining the vacuum in the tubes over such long distances. Nevertheless, plenty of engineering brainpower is being invested, and companies including Virgin Hyperloop One, Hardt Hyperloop and TransPod are all working on their own systems.

HELLO VERA

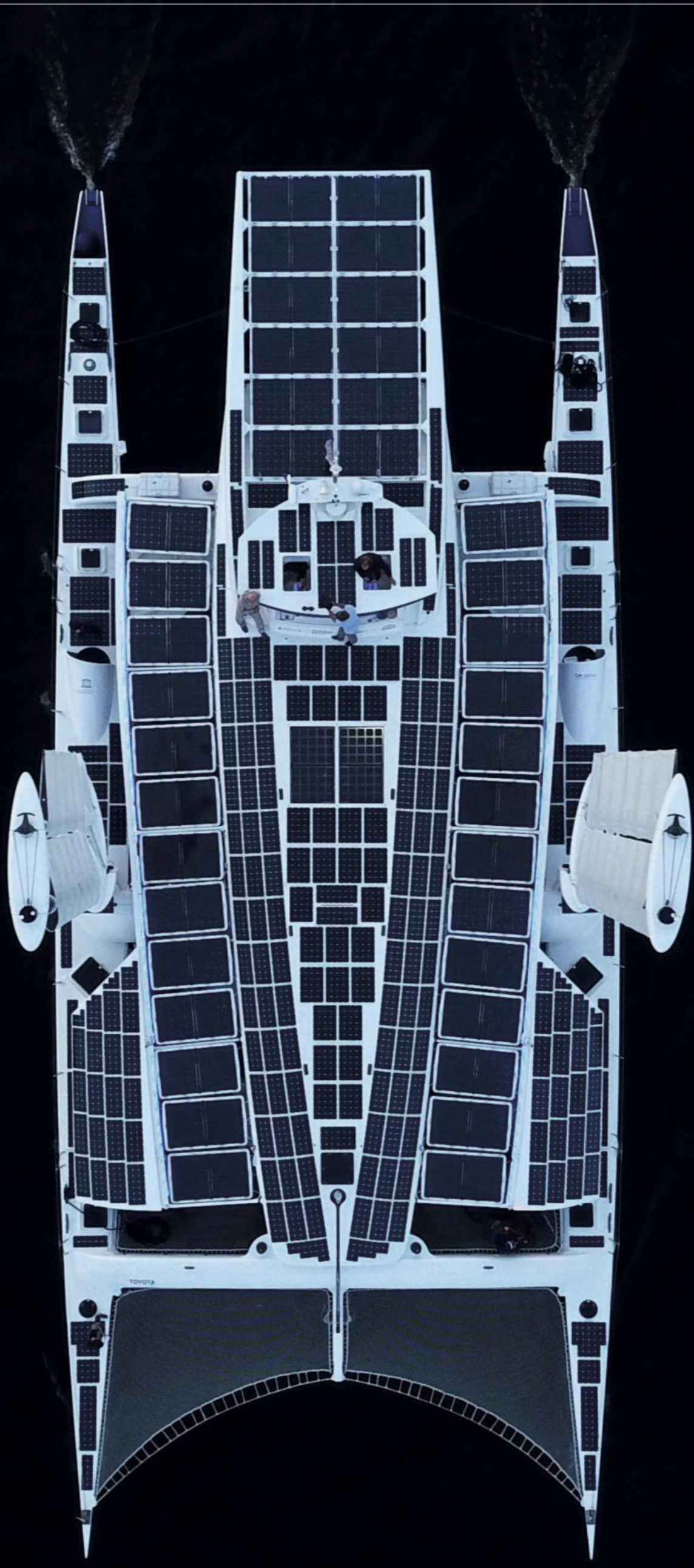
↓ VOLVO VERA TRUCK

Lorries of the future may be barely recognisable from the ones pounding up and down motorways today. Say hello to Volvo's self-driving truck Vera, which does away with a driver's cab entirely.

In spite of its sleek, futuristic looks, Vera is not just a concept vehicle. Volvo is working with shipping and logistics company DFDS on a system that would use these driverless trucks to haul goods five kilometres from a transport hub to a port terminal in Gothenberg, Sweden – a route that takes in public roads. It's expected to be up and running within five years. Vera navigates using onboard cameras and a system that builds up a 3D laser map of its surroundings. There's also a safety backup, enabling staff in the control centre to take control remotely if needs be.

"Driverless lorries are most likely to be used where you have a high volume of short, repetitive journeys," says Mikael Karlsson, vice president of autonomous solutions at Volvo Trucks. Longer, more complex journeys will still be left in the hands of human drivers – at least for now.

GETTY IMAGES, JEREMY BIDON



FLOATING INTO THE FUTURE

← ENERGY OBSERVER SHIP

It was once a racing catamaran that won trophies and broke world records, but this boat – now called 'Energy Observer' – has taken on a new life as a floating laboratory aimed at revolutionising how we power ships.

Its traditional sails have been replaced by a skin of cutting-edge solar panels that power electric motors. It's also the first ship to feature a hydrogen power generation system, using an electrolyser to split seawater into hydrogen and oxygen. The hydrogen is compressed and stored in tanks until it's needed, when a fuel cell converts the hydrogen back into water, releasing electrical energy in the process. Meanwhile, two rigid, 12-metre-tall 'Oceanwings' sit on either side of the 30-metre-long craft, providing extra wind propulsion when required.

Energy Observer is currently two years into a six-year world tour, the goal of which is to demonstrate how this green energy production and propulsion technology could be harnessed in future ships – important given that 90 per cent of global trade is transported by the sea.

↑ CONTROL CENTRE

It's from this cockpit that the crew steer Energy Observer and communicate with the outside world. Doors from the cockpit lead to the brains of the boat: the Energy Management System. Because different energy sources ebb and flow as conditions at sea change, the system is routinely switched between power sources to keep the craft running. For example, when solar power runs out at night, the hydrogen fuel cells are brought into action to convert the stored hydrogen into electricity.

YELLOW CAB

↑ CORA AIR TAXI

How often have you been sat in traffic, wishing you could just fly above it all? Well, Cora, a flying electric taxi, could be the answer.

It's piloted autonomously, which means that pretty much anyone could fly in it without training. Twelve lift fans get Cora off the ground vertically, before it flies like an aircraft using a single propeller at the rear. This means it could take off from a car park or the roof of an office building, carrying its two passengers home – as long as they live within its 100-kilometre range.

Kitty Hawk Corporation, the California-based company behind Cora, envisages that you would book a trip aboard much like you do with an airline or a ride share. But how soon we'll be able to do that is unclear – Cora still needs regulatory approval before it can operate commercially. There's good reason to believe it will happen, though: Kitty Hawk is funded by billionaire Google co-founder Larry Page and is working with both Boeing and Air New Zealand.

TELEPATHIC TRANSPORT

→ MERCEDES-BENZ FUTURE BUS

Bus rides are set to get a 21st-Century makeover. The Mercedes-Benz Future Bus is fitted with a GPS system, cameras and radar, so it can drive itself along its route, stopping to pick up passengers along the way. All the driver needs to do is watch out for hazards, intervening with a dab on the brake or a touch of the steering wheel.

Future Bus has other tricks up its sleeve, too. Perhaps the most impressive is its ability to 'talk' with traffic lights using its 'vehicle to infrastructure' system, so it can find out when they are about to change, gently slowing down if necessary. All of this technology is designed to provide passengers with a smoother service and relieve the workload on drivers.

Although Future Bus was successfully tested on a 20-kilometre route from Schiphol Airport in the Netherlands, it will still require several million kilometres' more testing before it can go into production. But Mercedes owner Daimler says that these kinds of technologies will be increasingly built into its buses in order to assist drivers. SF

by **ANDY RIDGWAY**
(@AndyRidgway1)
Andy is a lecturer and science writer based in Bristol.

EAT YOURSELF HAPPY

YOUR BODY HOSTS A COLONY OF CREATURES THAT BUILD THEIR LIVES AROUND YOU. NOW, SCIENTISTS ARE BEGINNING TO SEE THAT NOT ONLY DO THEY INFLUENCE YOUR HEALTH, THEY CAN EVEN CHANGE YOUR MIND TOO. WELCOME TO THE WORLD OF PSYCHOBIOTICS

ILLUSTRATION: MAGIC TORCH

by SIMON CROMPTON

There's a school of thought that says you are not one single organism, but rather a superorganism made up of many. Human cells make up less than half of what you call 'you' – the rest are trillions of bacteria, fungi and viruses in your gut, on your skin and throughout your tissues. You need them because of the role they play in digesting your food and maintaining a healthy immune system. They need you because they need somewhere to live.

Now research is providing evidence that you have an extra reason to treasure the microbes living in the depths of your bowels: if they're happy, you're happy too. The hitherto ludicrous-sounding idea that what happens in your intestines affects your mood has now got scientific backing. And it's become clear that it's your gut bacteria that are doing the communicating with your brain and affecting your state of mind.

Scientists are providing evidence for this link, which they refer to as the 'microbiome-gut-brain axis'. Not only that, but they are showing that altering your gut bacteria (microbiota) by administering probiotics (live bacterial supplements) and prebiotics (dietary fibre supplements that encourage bacterial growth), you can actually improve stress response, reduce anxiety and mitigate the effects of other mental health problems.

These findings are giving rise to a whole new class of medicines: psychobiotics. The hope is that they will eventually provide powerful new treatments for depression and other mental health conditions, as well as helping us to deal with everyday stress and anxiety.

This year a large review of studies found that probiotics yielded a small but significant effect in reducing anxiety and depression. A smaller study, published in the journal *Translational Psychiatry*, found that introducing a *Bifidobacterium* probiotic into the guts of healthy volunteers reduced their feelings of stress and improved their memory.

"I think the link is pretty strong," says Tim Spector, professor of genetic epidemiology at King's College London. "I'm not meeting ➤

anyone in the field who is saying there's no link between your gut microbes and mental health."

EVIDENCE OF THE BRAIN-BIOME LINK

Such mind-body associations sound like they belong to the province of alternative medicine. But doctors have long known that mental health problems, such as bipolar disorder and even autism, are often associated with gut problems, for example inflammation. Until recently, the main clues that this had something to do with the bacteria in our bowels came from animal experiments. Studies on mice indicated that the bacteria in their guts were creating some sort of pathway between their bowels and their brains.

For example, research from the University of Colorado Boulder has shown that stress disrupts the normally stable relationship between gut bacteria and their host, resulting in gut inflammation. Giving rats a probiotic containing a bacterium known to be important to immune system function not only clears up the inflammation but reduces stress-related behaviour.

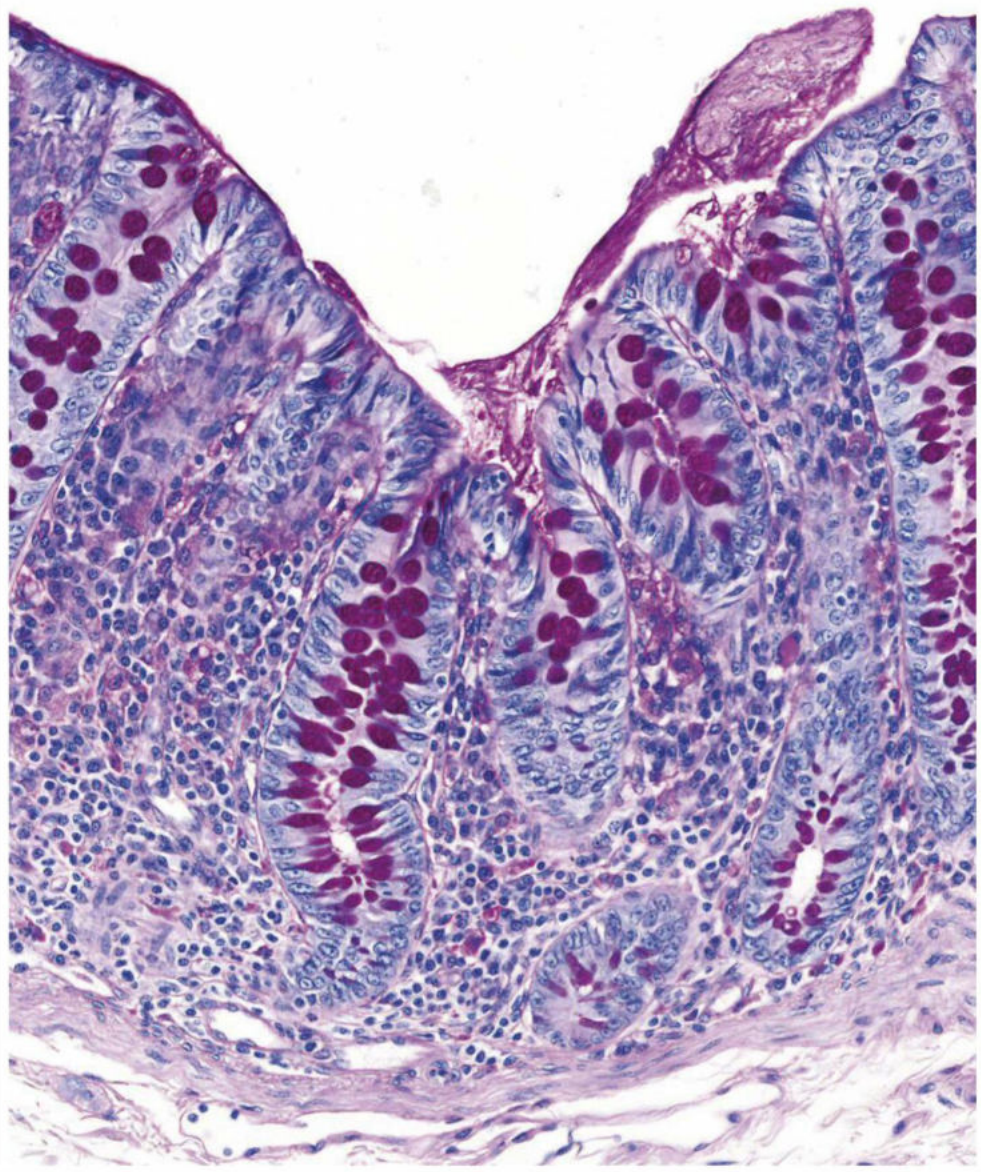
Only in the past year have large population studies provided strong evidence that the same principle applies to humans. Patterns of anxiety and depression tally with certain patterns of gut microbes. An analysis of data from more than 1,000 people in Belgium and Holland found that the presence of some types of gut bacteria was consistently associated with higher quality of life, while their absence was consistently associated with depression. After the results were published, author Prof Jeroen Raes, a microbiologist at Belgium's Katholieke Universiteit Leuven, said: "If you would have asked a neuroscientist 10 years ago whether they thought the gut microbiota could be linked to depression, many of them would have said you were crazy."

Spector, whose microbiome research forms the basis of his book *The Diet Myth*, agrees that new studies are making scientists think differently. "But we still haven't done the really big studies in humans," he says. "We're over the first hurdle of saying there's a link, but we're a long way from pinning down the exact mechanisms and treatments."

HOW THE LINK WORKS

The Alimentary Pharmabotic Centre (APC), part of University College Cork, Ireland, is at the forefront of trying to explain the microbiome-gut-brain axis. Scientists there were the first

"THE BRAIN NEEDS A CONSTANT SUPPLY OF TRYPTOPHAN AND THE MICROBIOTA PLAY A PART IN PROVIDING IT"



RIGHT The wall of the large intestine

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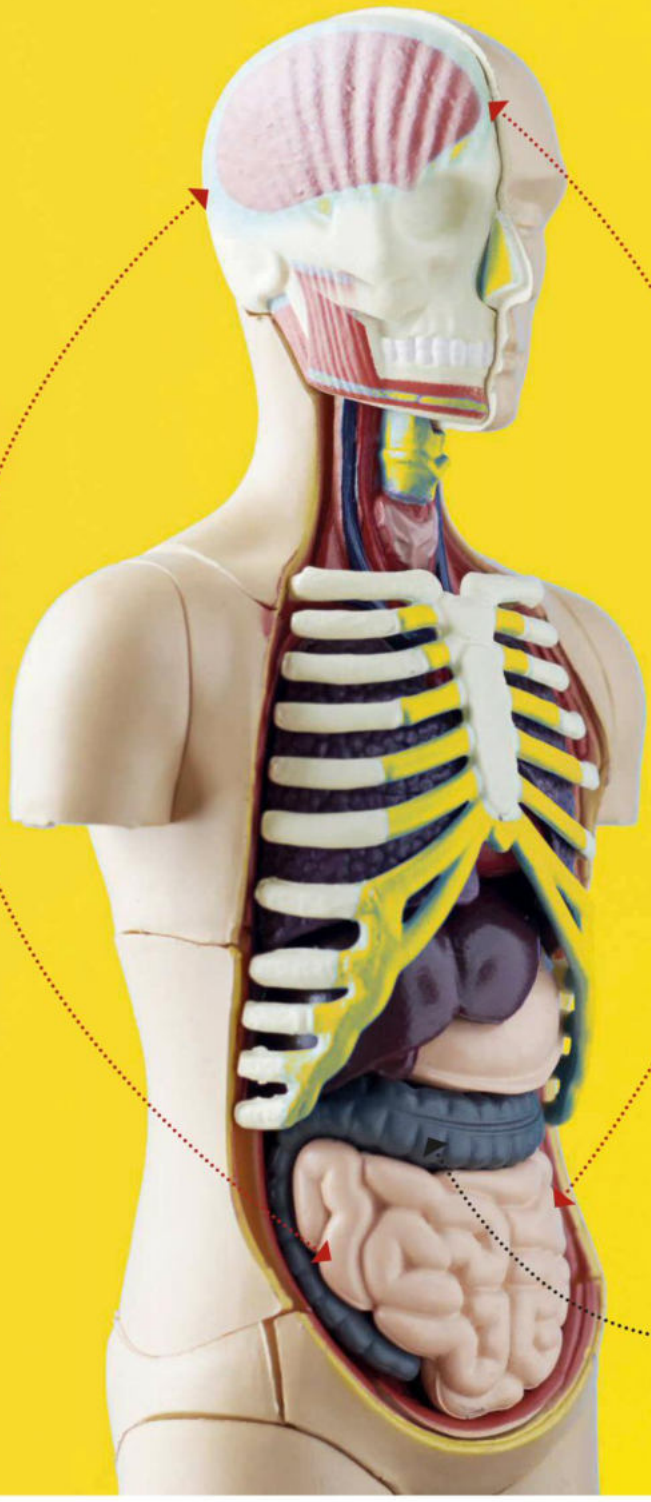

MICROBIOME-GUT-BRAIN AXIS

It's thought that there are as many bacteria living in you as there are human cells in your body. The lodgers in your gut metabolise the food and drink you consume, eking out extra nutrients for your body as they do. But the diversity of these bacteria and the way they interact can affect the signals that are sent to your brain via the nerves and chemical pathways based in your digestive system. As such, any nutritional deficiencies in your diet that lead to a drop in the diversity of your gut bacteria population could have negative impact on your mental wellbeing.

to discover that transplanting gut microbes from a depressed rodent to a non-depressed rodent causes behaviour changes that indicate depression. They are trying to use this new knowledge to develop ways of making us healthier and happier.

According to Ted Dinan, professor of psychiatry at University College Cork and the APC's lead investigator on the microbiome-gut-brain axis, there are three likely communication routes between gut microbiota and the brain.

First, chemicals produced by bacteria may influence signals being sent from the millions of nerve endings in the digestive system to the brain via the vagus nerve, which runs all the way from the colon to the brain stem.

Second, research at the APC has indicated that some gut bacteria such as *Bifidobacteria* produce an amino acid called tryptophan. This is an important building block for the neurotransmitter serotonin – an essential brain chemical known to influence mood. "The brain needs a constant supply of tryptophan and the microbiota play a part in providing it," says Dinan.

The third possibility is that bacteria are influencing gene expression in the brain. When microbes digest fibre, short-chain fatty acids are released as a by-product. It now seems likely, explains Dinan, that these acids travel through the bloodstream to the brain, where they act as epigenetic modulators, reprogramming some brain functions and influencing mood.

POTENTIAL TREATMENTS AND PREVENTION

Researchers at the APC are focusing on the effects of probiotics and prebiotics on healthy volunteers, rather than those with clinically diagnosed depression. But already the evidence suggests doctors will, one day, be recommending such supplements to fill microbiota gaps that may be contributing to their patients' mental health issues.

"We will see a scenario where probiotics or prebiotics will be recommended for people with milder forms of depression or anxiety," says Dinan. "We don't have the trials at the moment to make those ➲

recommendations, but it will happen in the future." Some of the most exciting potential lies in conditions for which treatment is currently difficult, ineffective or brings unpleasant side effects. There is some research indicating that microbial transplants might be of use in people with autism spectrum disorders (ASD). Arizona State University researchers have reported that by treating the gastrointestinal problems of children with ASDs with a transplant of microbes from a healthy donor, they also brought about improvements in language skills, social interaction and behaviour.

In the battle against depression, which is triggered by a complex mix of genetic and environmental factors, probiotics could provide another weapon. "The effect size is pretty small for most pharmaceutical antidepressants, so the evidence so far is that some of these probiotics might do just as well as the more commonly prescribed drugs, which can have dangerous side effects," says Spector. His twin studies have indicated that, although genes are clearly important in determining who gets depression, adjusting the microbiome can help override genetic factors. "That gives me a lot of optimism," he says.

There may also be a role for probiotics and prebiotics in promoting longer-term mental health, even if someone has had a previous mental health episode. A fascinating trial by researchers in Baltimore found that giving probiotics to people discharged from hospital following a 'manic' phase of bipolar disorder significantly reduced their chances of being re-hospitalised.

THE DANGERS OF HYPE

Sadly, we're unlikely to see any of these treatments very soon. One problem is that there are currently no dose studies showing how much of a probiotic you have to take to make a difference. Another problem, says Spector, is that every person's microbiome is different. "That means that one standard treatment won't work on everybody, so we may well end up needing personalised probiotics, which will be expensive."

"THERE IS NO QUESTION THAT A POOR DIET IS LINKED TO POOR MENTAL HEALTH"

IS THIS THE HAPPINESS DIET?

FRESH FRUIT AND VEG, FISH AND OLIVE OIL

The 'Mediterranean diet', long touted for its heart health benefits, is now being recommended as a diet that can make you happy because it encourages a diverse and healthy gut microbiome.

Scientists and health professionals define the Mediterranean diet loosely: eating lots of fresh fruit, vegetables, beans and lentils, nuts, whole grains and olive oil; occasional fish, chicken, eggs and dairy; and avoiding red meat, sweets, cakes and biscuits. The traditional foods of Cyprus, Croatia, Greece, Italy, Morocco, Portugal and Spain all generally fit the bill.

In October last year, a review of evidence from four large diet studies involving 36,000 adults from Spain, France, the United Kingdom, Australia and the United States, concluded that people who follow this kind of diet have a 33 per cent lower risk of depression than people who don't. Separate research presented to the American Psychiatric Association this year also suggested that keeping to a Mediterranean diet protects against depression in later life.

Prof Ted Dinan, principal investigator at the Alimentary Pharmabotic Centre (APC) at University College Cork, says the secret of the diet is the diversity of plant products it introduces into the gut, thus encouraging a wide range of microbes to thrive there.

The (APC) is currently investigating what happens when people change to the diet. Early findings are that, in people who experience improvements in mental health as a result of going on the Mediterranean diet, there are significant changes in gut bacteria not apparent in control groups.

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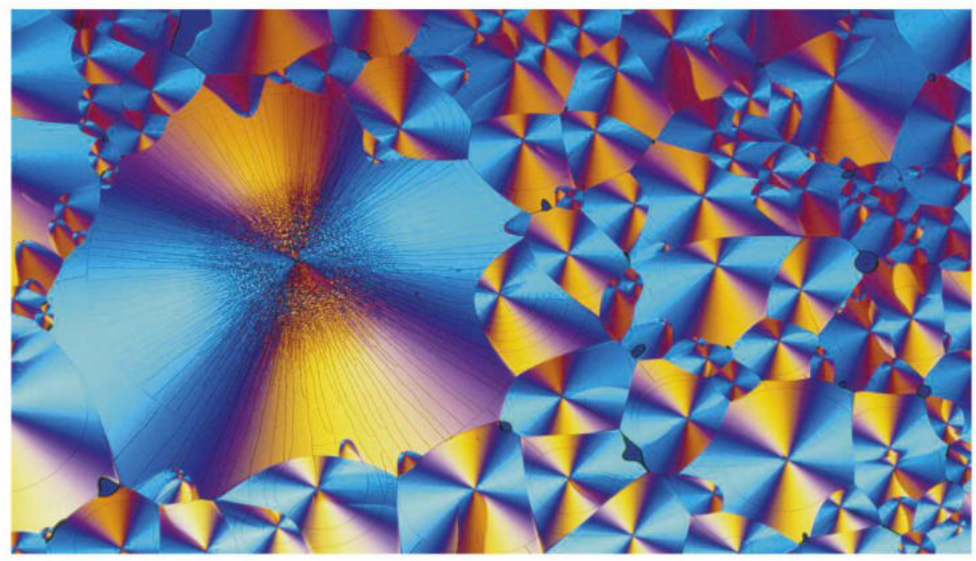
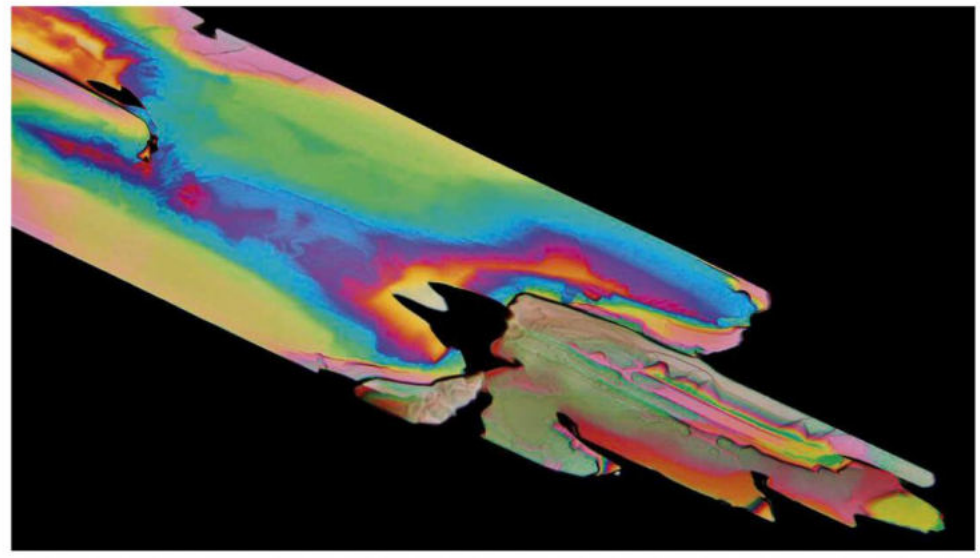




ABOVE Prof Ted Dinan says that lots of plant-based foods can help boost the microbiome

TOP RIGHT Studies suggest that some gut bacteria produce tryptophan (pictured) which is a building block of serotonin

ABOVE RIGHT Serotonin (pictured) is a neurotransmitter that plays a key role in mood regulation. Low serotonin levels are linked to depression

The public too have become wary. The hype that has surrounded probiotic and prebiotic food products, with companies claiming that sugary products with added bacteria improve gut health and boost your immune system, has often not been backed up by good science. The danger now is that the genuine promise of psychobiotics may be underestimated. "Regulation of the food industry has been very lax in the past, so people have been able to make a lot of claims without very good data," says Dinan. "Fortunately, I think that's changing now."

GOOD DIET, GOOD MENTAL HEALTH

But waiting for new psychobiotic treatments may be overlooking the single most important lesson from this research: that our diet has a crucial effect on our mental health. Psychiatrists and dietitians have, for years, been saying that changing our eating habits can make us happier, or at least help keep us on an even emotional keel.

"We may not have the trials at the moment to make exact recommendations," says Dinan. "But I'm of the view that, even now, in psychiatry, there is no question that a poor diet is associated with poor mental health. I run clinics for people with severe forms of depression who are not responding to antidepressants and if you give them appropriate dietary advice, in association with antidepressants, there's no doubt you can get responses that you don't get with the antidepressants alone."

Dietary diversity is the key. The reason that probiotics work as treatments is that they fill a gap in your gut microbiome that disrupts its normal functioning. There's enough evidence to suggest that a wide-ranging diet results in a microbiome full of different types of bacteria and leads to better mental health. A diversity of plant-based food is particularly important, says Dinan (see box, opposite page). He points out that studies have indicated that, because of the rise of processed food, most of us have many fewer different types of gut microbes than our grandparents and great grandparents. "We're missing microbes," he says. "That might mean we're dealing with stress less effectively."

Spector agrees. "I do think the first thing to do before thinking about probiotics is to improve your diet first. We have to realise that one of the reasons we're getting so much depression and anxiety in the UK is because of our very poor diet and our high rate of eating processed food. We need to get our diet diverse and cut out the chemicals before thinking about psychobiotics." **SF**

by **SIMON CROMPTON** *(@Simoncrompton2)*
Simon is a freelance health writer.

SECURITY OF ANOTHER STRIPE

Take control of your data security and protect yourself from digital threats with Stripe OLT

You lock your front door, don't you? You brush your teeth, you wear a seatbelt. Yet when it comes to data security, many of us choose to adopt a less scientific approach – one that involves burying our heads in the sand and crossing our fingers.

We shouldn't. Cybercrime is big business, costing UK companies up to £30BN year, while phishing scams cost private individuals up to £190,000 every day, according to police. And it's a threat that's constantly evolving, because as quickly as new technologies emerge – from the cloud to the Internet of Things – cybercriminals figure out new ways to exploit them. Cryptojacking, for instance – hijacking users' PCs to mine cryptocurrencies – is just one of many emergent threats, and affected up to 55 per cent of UK business in 2017 alone.

The costs of poor data security can be devastating: remember the NHS data breach in July 2018, which saw 150,000 patients' confidential data used (against their wishes) for research? Such attacks can result in threats to the safety and privacy of individuals, as well as harming both a company's bottom line and its reputation. So with companies relying ever more heavily on cloud computing and artificial intelligence to store and process our data, it's imperative that adequate security measures are in place.

However, data security isn't just a corporate responsibility: it's becoming personal. Flexible working, for instance, means our personal devices are increasingly used in the workplace, presenting a whole new set of security challenges. From data leaks and insurance implications to device theft and loss, we need to ensure we're doing everything we can to safeguard access. Few people realise, for instance, that simply installing a password manager will make data on their devices up to 80 per cent safer.

With business security and personal responsibility increasingly intertwined, companies like Stripe OLT are essential: they keep business systems secure, compliant and protected with robust security services and employee training. From the implementation of Microsoft's Advanced Threat Protection, to attaining government best practice certifications like Cyber Essentials Plus, they cover everything you need to ensure your online security in the workplace.

As quickly as new technologies emerge – from the 'cloud' to the Internet of Things – cybercriminals figure out new ways to exploit them. Cryptojacking, for instance – hijacking users' PCs to mine cryptocurrencies – is an emergent threat that affected up to 55 per cent of UK business in 2017

TO FIND OUT MORE, CALL STRIPE OLT ON 0207 0437044, OR VISIT STRIPEOLT.COM FOR DETAILS ON UPCOMING CYBER SECURITY EVENTS

Stripe OLT

COMMENT

TAKING THE PLUNGE

Cold water could have benefits – if you can pluck up the courage to dive in

Between June and September, I swim in the sea as often as I can. But quite apart from the pleasures of doing exercise in the great outdoors, what are the health benefits, if any, to be had from a dip in the ocean or a cold river?

A few years ago I made a film with Wim Hof, also known as 'The Ice Man'. Wim assured me that cold water can lead to a "cascade of health benefits", including fat loss, a strengthened immune system and the production of mood-boosting endorphins.

There is evidence that cold water encourages the development of brown fat (which burns calories) and clearly, if you do a lot of swimming in cold water then you are going to burn your way through a lot of calories. But I suspect most of us will not stay in long enough for this to have a significant impact on our body mass.

As for boosting your immune system, the jury is still out. There have been plenty of animal studies, but few randomised human trials. One Dutch study published in 2016 in the journal *PLOS One* recruited 3,018 people and randomly allocated them to having a cold shower every morning for a month, or to a control group. By chance, while the experiment was going on, there was an outbreak of flu and it turned out that those people having cold showers were 30 per cent less likely to take time off for sickness than those in a control group. Even better, a 30-second blast of cold water gave the same benefits as sticking to it for longer.

"Being in cold water increased their metabolic rate and boosted levels of dopamine"

But what about improving mood? Again, there's not a huge amount of research or randomised trials, but there was a rather brutal study from 2000 where scientists looked at the impact of keeping young men in a tank of chilly water (14°C) for up to an hour. Among other things they found that being in cold water increased their metabolic rate by 350 per cent and boosted levels of dopamine (a 'feel-good chemical') by 250 per cent.

There have, however, been some intriguing individual stories linking cold water swimming to improvements in mental health, like one published recently in the *British Medical Journal*. It looked at the case of a 24-year-old woman called Sarah who had been taking antidepressants since the age of 17. A couple of years ago she began a programme of weekly cold water swimming, which led to an instant improvement in her mood and in time she was able to come off medication.

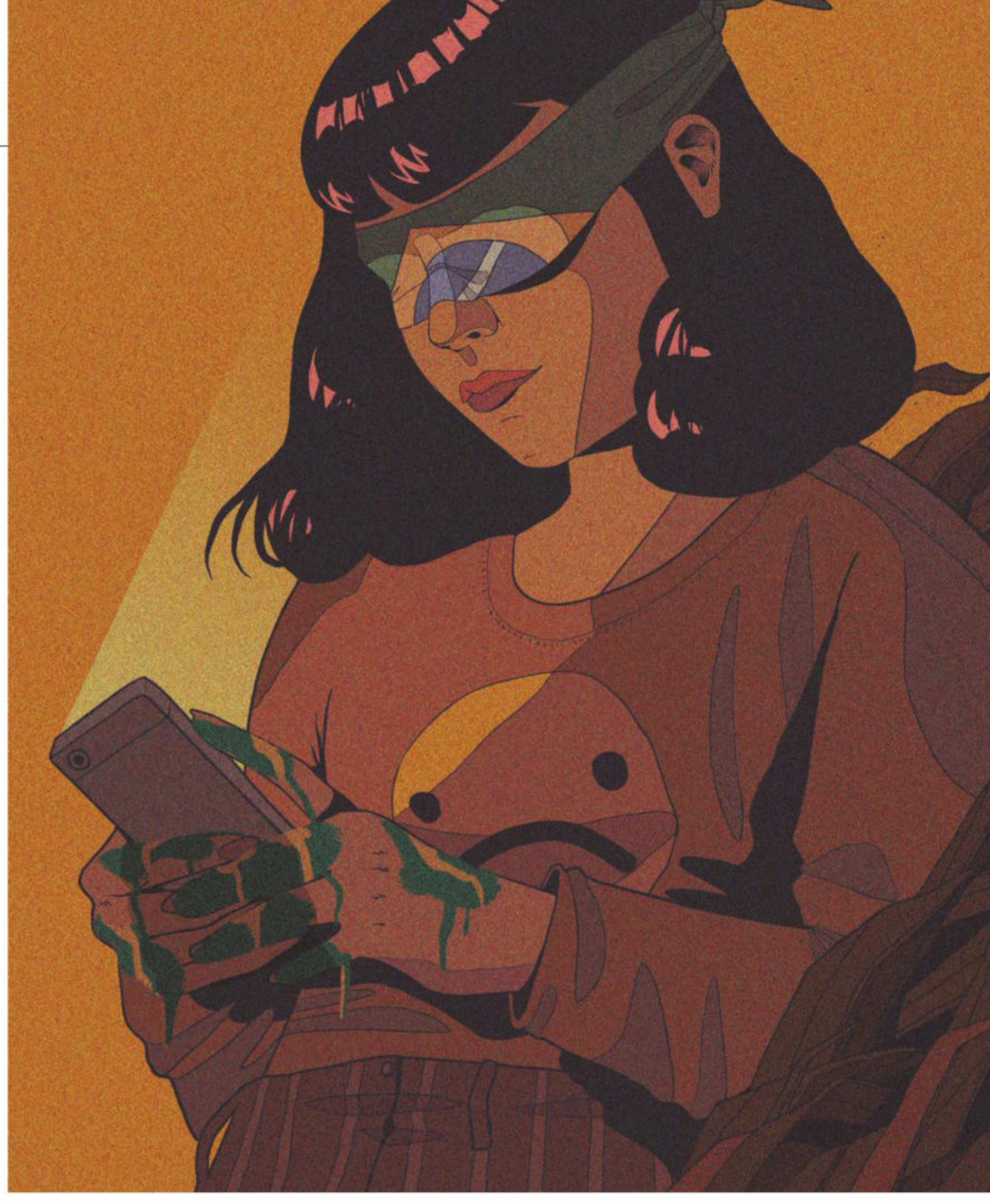
If you plan to go cold water swimming, be cautious and don't do it alone. If you are not used to the temperature of the water, your first, involuntary reaction to jumping in will be to take a gasp of air, and if you are underwater at the time this can be fatal. And as I discovered recently it can also wipe your memory, albeit temporarily, through a condition called 'transient global amnesia'. But that's another story… **SF**

MICHAEL MOSLEY

Michael is a writer and broadcaster, who presents *Trust Me, I'm A Doctor*. His latest book is *The Fast 800* (£8.99, Short Books).

BBC TWO

PORTRAIT: KATE COPELAND ILLUSTRATION: PEPE SERRA



COMMENT

THE PERILS OF UNEQUAL INTERNET ACCESS

How a lack of access to affordable information helped to radicalise Brazil

Pre-internet, analysts found that patterns of behaviour clustered in geographic areas. Anthropologists and human geographers studied the clusters of culture that formed within isolated social groups – whether in rural parts of the UK or tribes in remote Asia – and found patterns about how they structure their days and lives. Social psychologists recognise that finding yourself in one of these tight-knit, isolated communities predicts what you will believe.

Armed with this knowledge, many observers and experts predicted that access to all the world's information would create silos of opinion that we now describe variously as feedback loops, echo chambers and filter bubbles. There are other aspects of human behaviour that scientists have predicted will have a profound impact on our society. One of these is, what will happen if a system is set up that charges for different access to all the world's knowledge? Recent events in Brazil could offer us some insights.

Not long ago, two reporters from *The New York Times* went to Brazil to investigate a proposed link between messaging service WhatsApp, video-sharing site YouTube, and the rise of far right presidential candidate Jair Bolsonaro. They discovered that the poorest Brazilians – whose political revolution helped to usher in Bolsonaro – had fallen into a swirl of misinformation and conspiracy that supported the far right line, and was a specific result of an unevenly distributed information network.

> **"A non-neutral, economically divided internet will create echo chambers"**

Internet access is expensive in Brazil, and many mobile phone operators throw in unlimited access to the WhatsApp app for free as a contract sweetener. Even if you can't afford an internet plan, which means no YouTube or Google, you can still connect for free in the closed social groups you form via WhatsApp. And whatever passes through that silo becomes your news diet.

Illiteracy in poor communities is incredibly high, so text isn't the primary form of communication. Instead, video clips snipped from YouTube (too expensive) are uploaded to WhatsApp (free), where they're viewed and shared.

According to the authors, the Brazilian YouTube ecosystem had been hijacked by conspiracy theorists who jumped onto issues of interest to the poor communities, and they created compelling and algorithmically tasty content that was fed into the WhatsApp closed groups without context. And because these users weren't able to check for veracity on Google (too expensive), their news diet became unbalanced. The authors drew a direct link between a two-tiered, unevenly distributed access to information and the rise of fear and rage against opponents of Bolsonaro.

The internet is already positioned to service our desire for silos of opinion, which we know can lead to changes in behaviour. A non-neutral, economically divided internet will create echo chambers of manipulated and unverifiable information that will continue to have real-world consequences. We are devastatingly predictable animals, after all. SF

PORTRAIT: KATE COPELAND ILLUSTRATION: GUSTAVO PERGOLI

ALEKS KROTOSKI

Aleks is a social psychologist, broadcaster and journalist. She presents *Digital Human*.

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INTERVIEW

THE PLIGHT OF THE HUMBLE BEE

Our way of life depends upon bees, but these insects are under threat. **Amy Barrett** talks to **Samantha Alger**, an environmental scientist and pollinator specialist, about her work uncovering the secret lives of bees

JOSHUA BROWN

“Bumblebees were more likely to be infected by viruses when they were near honeybee apiaries. We also found evidence that transmission of viruses could be occurring through shared use of flowers”

WHY DID YOU START STUDYING BEES?

I had an opportunity to study tropical ecology and conservation abroad, and I realised that you can be a biologist and study insects for a living – which was ludicrous to me, who grew up in a household where you could be a doctor or a lawyer. I didn’t know that these things existed.

I knew I was interested in conservation, but I wanted to focus my efforts on something that was important not just for conservation in a tree-hugger sort of way, but also important for humans. I found out that you need bees for one of every three bites of food. They provide pollination services for most of the food that we eat, so the connection there was really strong. It’s good for wild bee conservation, but also, it’s important to humans.

WHAT KIND OF THREATS ARE FACING BEES?

The media will say ‘oh, it’s this chemical. It’s RoundUp, or it’s neonicotinoids, or it’s this one disease.’ Everyone wants to point their finger to a single smoking gun, but it’s a combination of threats, including habitat loss. With land-use change we see vast areas that are getting converted to corn or parking lots, for example, which offer nothing for bees. Areas that were once really good for foragers are changing, so they are losing habitat, foraging and nesting resources.

We also know that bees are affected by disease. Of course, there’s a tonne of different pests and pathogens that both managed and wild bees are affected by, but I think that the most concerning issue is the introduction and spread of novel or exotic pathogens to native hosts.

Also pesticides and herbicides are another threat. If you’re using herbicides to kill the wildflowers or what we think of as weeds, that’s affecting their foraging areas. Pesticides that we put on our crops to keep herbivores from eating them can also affect bees.

YOUR LATEST RESEARCH FOCUSED ON THE SPREAD OF DISEASE BETWEEN BEE POPULATIONS. WHAT DID YOU FIND?

We wanted to see if diseases, or specifically viruses, are spilling over from managed honeybees into wild bumblebee populations. This is something that had been suggested by researchers, but hadn’t been tested. We found compelling evidence that this is happening. Bumblebees were way more likely to be infected by viruses when they were near honeybee apiaries. We also found evidence that this transmission of viruses could be occurring through the shared use of flowers.

A high proportion of flowers near honeybee apiaries – about 19 per cent – harboured these viruses, whereas all the flowers we collected in sites where there wasn’t a honeybee apiary nearby were all negative for the viruses.

HOW DOES THAT SPILLOVER HAPPEN?

We don’t really know what the mode of transmission might be. We don’t know whether it’s through salivary secretions or through faeces, but those are the two most probable methods.

When bees forage on flowers, you can think of a flower like a dirty doorknob during flu season, right? In the disease ecology world, we call it a ‘fomite’, sort of an inanimate object that might harbour a pathogen. Imagine a honeybee landing on a flower. What they’re doing on that flower is walking around on it, getting pollen on their bodies, sticking their tongues in the flowers and drinking up the nectar. Once they get pollen, they sort of coat it in salivary secretions and then stick it to the sides of their bodies. Then they’ll travel to the next flower and do the same thing. Some of those pollen grains that they might have put saliva on fall off their bodies onto that flower, and also during that process, they will often defecate and leave behind faeces.

It’s funny, we look onto our beautiful gardens and we see bees pollinating plants and we’re not thinking about all these gross faeces and salivary secretions that can be left behind by bees. But that’s how we think this is occurring. Another bee will land on that flower and they’re basically feeding from the same waterhole, right? They can then possibly pick up viruses through the salivary secretions or the faeces left behind.

WHERE DO THESE VIRUSES COME FROM?

Viruses have been around for a long time. They really only became a big problem in honeybees

SAMANTHA ALGER

Samantha is a researcher in the plant and soil science department at the University of Vermont. She also works as an environmental scientist and pollinator specialist at an engineering consulting firm called VHB. At VHB, Samantha helps US departments of transportation and other big organisations change management practices to reduce how often they mow roadside areas or vast areas of land, cutting their costs and improving local pollinators’ habitat.

JOSHUA BROWN

Samantha Alger:
environmental scientist
and friend to bees

with the introduction of the *Varroa* mite to North America, Europe and elsewhere. That mite came from Asia and transmits the viruses directly to the haemolymph – the blood – of the bee. Then the viruses are able to propagate quickly and cause symptoms in the honeybees, whereas previously, honeybees might eat a virus and it would go through its digestive tract and it might not actually be able to get into the bee's system at large and cause issues.

IF THE *VARROA* MITE CAME FROM ASIA, HOW DID IT COME TO BE PREVALENT IN HONEYBEE POPULATIONS ELSEWHERE?

It's a topic of a lot of research, but we don't really know where exactly it started and how it spread so quickly, except that it's just a really, really good parasite of honeybees. I think it was introduced to the US in the late 1980s [it arrived in the UK in the early 1990s], and since then we've come up with a slew of different chemical treatments, conventional, organic. There are different cultural practices that beekeepers employ to keep the mites at bay.

Those methods have been developed over time, and in some ways they're working, but we're never going to eradicate *Varroa* mites. They're here, and it's just a matter of managing. But there is another mite, the *Tropilaelaps* mite, that's in Asia. There are scientists studying it and it also looks to be spreading. There's a concern because the *Tropilaelaps* mite could actually out-compete the *Varroa* mite. With what we've learnt with the spread and the issues that the *Varroa* mite has caused, we're hopefully taking precautions now. There are researchers studying *Tropilaelaps* in its environment and trying to formulate mite-management strategies before it spreads.

WHEN WE THINK OF SAVING THE BEES, WE OFTEN THINK OF HONEYBEES. SHOULD WE FOCUS OUR EFFORTS ON OTHER TYPES OF BEES?

I think we should definitely broaden our efforts onto other bees. The public and conservation initiatives have focused so much on honeybees because people know what a beekeeper looks like and people know how bees are kept in this incredible comb in this hexagonal structure. It's all very charismatic and people understand it. Whereas if you talk about a solitary bee that nests underground in these little, tiny holes, it's difficult for people to feel like they're connected to that and to try to make changes based on this bee. But if all of the effort is focused on the honeybee, then we're missing the vast majority of species in the world. There are 20,000 species of bees. If we're finding that honeybees are causing problems for other bees, either through the spread of disease or through maybe competition on flowers, that's a difficult thing to show people.

1. Honeybees are used worldwide for pollination and honey, but they can transmit deadly viruses to wild bee species, which are also important pollinators and a vital part of the ecosystem

2. 'Messy' land is a hugely important habitat for insects like wild bees

3. Samantha collecting bumblebees as part of her research

JOSHUA BROWN X3

“We need to change our mentality of what is beautiful. We need to think that if we have a messy lawn, we’re supporting bees, and that’s a beautiful thing”

3

IT’S A REAL SHAME THAT BECAUSE SOLITARY BEES AND BUMBLEBEES DON’T SEEM TO OFFER ANY BENEFIT TO HUMANS, WE’RE NOT AS WORRIED ABOUT THEM…

Well, I wouldn’t say they don’t offer benefits to humans. They are fantastic pollinators of crops. It’s just a matter of making sure there’s the habitat to support them.

In Vermont here, we’re pretty rural, we have farming communities structured in such a way that the farms tend to be pretty small and we have a lot of wild habitat between farms. Research by my colleagues at UVM found that blueberry growers produced way more blueberries when they had wild habitat around their farms, and that their blueberries were supported by other bees. So, they’re fantastic pollinators. It’s just a matter of being able to support them around our crops to take advantage of that free pollination service.

It’s not that they’re not doing anything for us; they are. It’s just that people don’t associate with them. They don’t have that childhood curiosity or interest with other bees, because they hadn’t been introduced to them at such a young age as they had been to honeybees.

WHAT CAN WE DO TO HELP WILD BEES?

There’s two big things. One would be to do whatever you can to create pollinator habitat. Bees like really messy, messy fields. You know? We’re talking about snag, like trees that have died that are still standing, and they have holes in them. We humans don’t like to look at those and we like to take them down. But that’s incredible bee habitat. Messy brush piles or areas where there are clumps of grass that bumblebees can nest down into and burrow into, not that beautiful cut grass that might be cut at an angle: that’s basically a desert for bees – all things that we view as not aesthetically pleasing. We need to change our mentality of what we think is beautiful. We need to think that even if we have a messy lawn, we’re supporting bees, and that’s a beautiful thing.

The other big thing is to avoid using pesticides and chemicals on our home gardens. Homeowners are not necessarily trained how to use pesticides, how or when to apply them. It’s not really the quantity of these chemicals being used, it’s the way that they’re being misused.

It’s funny, I think being in this position of a bee researcher and an advocate for bee conservation, a lot of people come up to me and say, “I’m thinking about becoming a beekeeper because I want to help save the bees. I want to do my part, so I’m going to become a beekeeper.” And you know, based on our discussion, you can see why that’s such a disconnect. It’s like wanting to do something for bird conservation, and then saying you’re going to become a chicken farmer.

It’s great that you want to take on that hobby, but beekeeping is a lot of work. It’s a lot of effort. You have to do a lot of things to keep your bees pathogen-free, and if you’re not willing to put in the effort, you actually could be causing harm to your own bees, to maybe your neighbour’s bees, and now to the pollinator community at large if your pathogens are spilling over. **SF**

DISCOVER MORE

You can listen to our full interview with Samantha in an upcoming episode of the Science Focus podcast
sciencefocus.com/science-focus-podcast

HOW TO SMASH AN ASTE

ROID

Two years from now, a craft will race across space on a suicide mission to smash into a space rock. Why? To help astronomers test the feasibility of deflecting dangerous asteroids that are on a direct collision course towards our planet

by DR STUART CLARK

Remember, the film *Armageddon*? It's the one where Bruce Willis climbs aboard a space shuttle, and uses a nuclear bomb to blow apart an asteroid the size of Texas just hours before it hits Earth and wipes out all life as we know it. Although the film can hardly be described as scientifically accurate, a new mission by NASA and the European Space Agency (ESA), called the Asteroid Impact and Deflection Assessment (AIDA), will attempt to make some of it come true.

In late July 2021, the first part of the mission, NASA's Double Asteroid Redirection Test (DART) will launch from Cape Canaveral on a suicide trip. The spacecraft will set course for the binary asteroid system Didymos, and after a 14-month chase, DART will smash straight into the space rock. The aim is not to shatter the target, but to change its orbital speed by a small amount – the kind of deflection that could save our planet should an incoming asteroid be detected.

AVERTING ARMAGEDDON

The threat from asteroids comes on a number of different scales, none of them good. At the most extreme end are the so-called 'global killers'. These are asteroids larger than 10 kilometres in diameter. As the name suggests, it was an asteroid in this category that wiped out the dinosaurs 65 million years ago.

Thankfully, we don't need to worry too much about a repeat of that cataclysm. "We're 95 per cent sure we are not going to get whacked by a global killer in the next hundred years," says Prof Alan Fitzsimmons, an astronomer at Queen's University Belfast. We know this because planet-killing asteroids are relatively bright due to their size, and have been picked up in surveys over the past few decades. None of them are close enough to cause any sleepless nights at the moment.

BOTTOM LEFT When the asteroid entered the atmosphere over Chelyabinsk in 2013, it exploded, leaving contrails behind

TOP LEFT The shock wave from the explosion shattered windows and damaged some buildings, like the factory pictured here

ABOVE A large fragment of the asteroid plummeted into Lake Chebarkul, leaving behind an eight-metre hole in the frozen surface

GETTY IMAGES, ALAMY, SHUTTERSTOCK

It's a different story at the other end of the scale, where the asteroids are smaller and dimmer. "We've still not found the majority of smaller asteroids," explains Fitzsimmons. "Our catalogues are woefully incomplete at this stage – not through lack of trying but simply through lack of resources."

"WE'RE 95 PER CENT SURE WE ARE NOT GOING TO GET WHACKED BY A GLOBAL KILLER IN THE NEXT HUNDRED YEARS"

And this is a big concern. Asteroids between 100 and 300 metres across are dubbed 'city killers' because when they hit, they could easily devastate a city. In 1908, an asteroid at the lower end of this size range struck the Earth in the Tunguska region of Siberia, Russia. Thankfully, it was an uninhabited area and no one is thought to have died, but the destruction was astonishing. The impact blast flattened 2,000 square kilometres of forest. Had it taken place over central London, the devastation would have just about stretched to where the M25 is today.

In 2013, a 20-metre asteroid entered the atmosphere over the Russian city of Chelyabinsk. It exploded in mid-air, creating a shock wave that shattered windows across the city, injuring around 1,600 people.

"When one balances the likelihood of impact with how many of those kinds of asteroids are out there, it's likely that the biggest threat to us is from a currently unknown asteroid between 100 and 300 metres across," says Fitzsimmons. "It will lay waste to whatever it hits, and if it's 300 metres across that will be a very large area: about the size of a small state."

The European part of the AIDA mission is called Hera, named after the Greek goddess of the starry heavens. This spacecraft will arrive about three years after DART's impact to study the results of the cosmic smash-up. And as unlikely as it seems, part of the reason it exists is probably down to that glitzy Hollywood blockbuster.

"It was not so long after the film *Armageddon* that people were wondering what the real space agencies would do in that situation," says Ian Carnelli, the manager of ESA's discovery and preparation team, located at ESA's headquarters in Paris. That early round of interest led to ESA putting together a team of experts called NEOMAP, the Near Earth Object Mission Advisory Panel, of which Fitzsimmons was a member.

ABOVE The DART craft is due to arrive at Didymos in 2022, where it will smash into Didymoon

They came together in the early 2000s to assess missions that could address threatening asteroids. They decided that the best option would be a deflection test like AIDA, but it came at a cost. "It was clear from the very beginning that this was an expensive mission and would require international collaboration," says Carnelli.

PICKING A TARGET

There was another stumbling block to a deflection test: technology. The original mission targeted an asteroid known as 2002 AT4, and would attempt to alter its velocity by around 0.5 millimetres per second. But trying to measure this minuscule change was particularly difficult because the asteroid was travelling around the Sun at 30 to 40 *kilometres* per second. Astronomer Dr Andrew Cheng of Johns Hopkins University came up with a solution. Instead of targeting a single asteroid, he suggested to find a pair that are in orbit around one another and target the smaller of the two. That way the 0.5

"ASTEROID AND COMET IMPACTS ARE THINGS THAT WE CAN DO SOMETHING ABOUT"

NASA/JOHNS HOPKINS

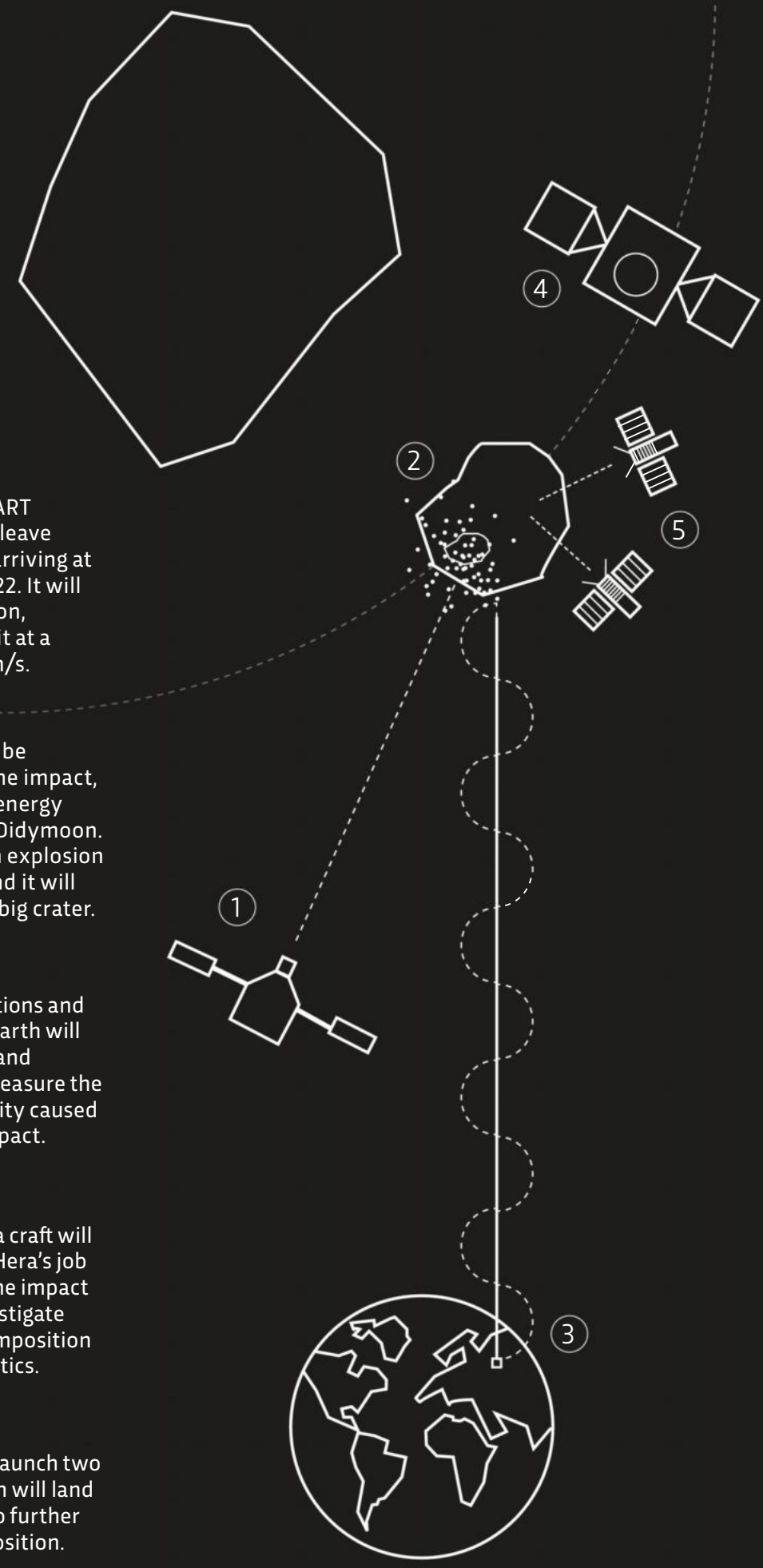
millimetres per second will be much easier to measure because the pair will only be moving around each other at a few centimetres per second.

This is where the asteroid Didymos comes in. It was discovered back in 1996, and was shown to be a pair of asteroids in 2003. The largest is 750 metres in diameter, the smallest is 170 metres. Nicknamed Didymoon, the little one is the target for DART because it is in exactly the size range that Fitzsimmons and other experts think is most dangerous to Earth.

The DART mission is a crucial experiment for humankind to conduct for one very good reason. “Unlike any other natural disaster, asteroid and comet impacts are things that we can actually ➲

THE AIDA MISSION

Didymos – meaning ‘twins’ in Greek – is a binary asteroid system consisting of two asteroids orbiting each other. The smaller of the two is nicknamed Didymoon. The AIDA mission will smash into Didymoon to change its velocity, to investigate how we could deflect asteroids on a collision course with Earth.



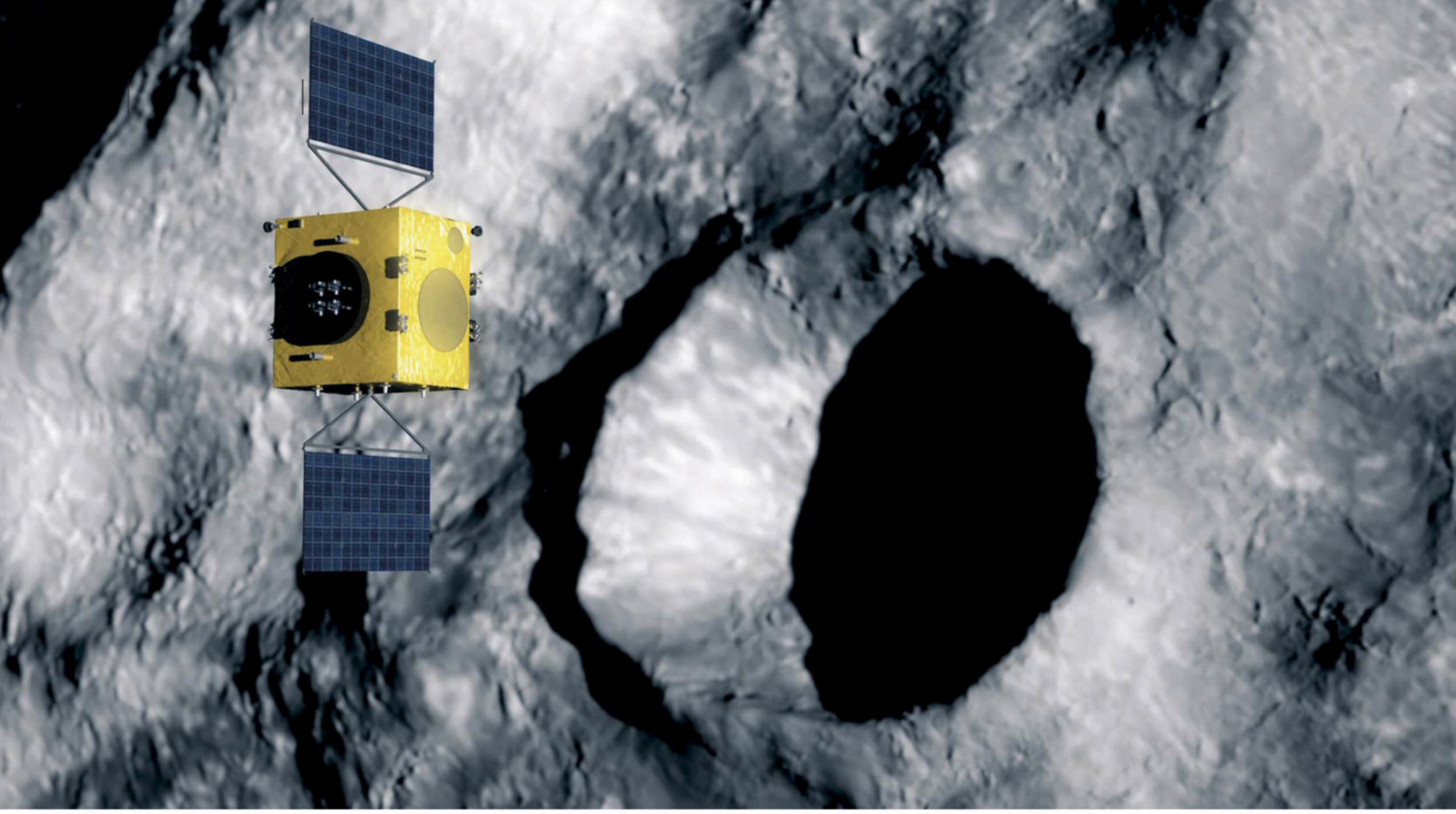
1 NASA’s DART spacecraft will leave Earth in 2021, arriving at Didymos in 2022. It will target Didymoon, smashing into it at a speed of 6-7km/s.

2 DART will be destroyed by the impact, and its orbital energy transferred to Didymoon. It will be like an explosion has gone off, and it will leave behind a big crater.

3 Radar stations and telescopes on Earth will track Didymos and Didymoon to measure the change in velocity caused by the DART impact.

4 ESA’s Hera craft will arrive in 2025. Hera’s job is to measure the impact crater, and investigate Didymoon’s composition and characteristics.

5 Hera will launch two CubeSats, which will land on Didymoon to further study its composition.



ABOVE Hera will investigate the impact crater caused by DART, assisted by a pair of CubeSat mini satellites

BELOW RIGHT Hera is due to set out from Earth in 2025, but only if funding can be secured

do something about," says Dr Andrew Rivkin of Johns Hopkins University, who leads the DART investigation. He points out that we can take precautions against the damaging effects of other natural disasters, by building earthquake-resistant houses, for example, but we can't prevent those disasters from happening. Planetary defence against asteroids is different because we *can* do something. "We can cause an impact not to happen," Rivkin says, "We have the technology to do this, and we now want to test it."

DART will close in on Didymoon at a speed of between six and seven kilometres per second, and will hit the space rock when it is roughly 11 million kilometres away from Earth. If the team pulls it off, it will be a staggering achievement in astronautics.

NASA does have some prior experience in this. In 2005, they smashed a spacecraft into comet Tempel 1. Known as the Deep Impact mission, it was a tactic designed to reveal the interior of the comet rather than try to deflect it, but it did give them valuable insight into such space targeting.

In the intervening years, computers and software have also come on apace. To zero in on Didymoon, DART will use software similar to that used at observatories to keep their telescopes pointing at the right target. After the impact, DART will be completely destroyed. "We expect to make a crater 10 to 15 metres across," says Rivkin.

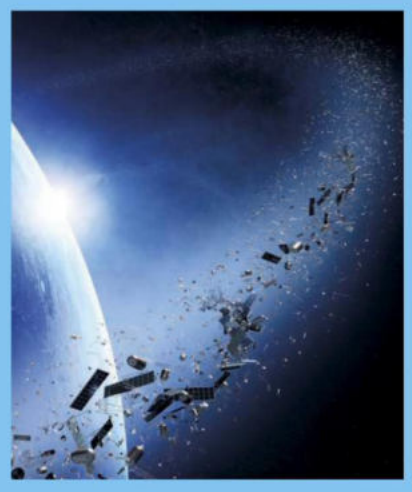
AFTER THE IMPACT

Once DART has carried out its mission, telescopes on Earth will begin tracking Didymos to see if Didymoon has been deflected. Then, in 2025, Hera is scheduled to arrive to begin its work. The European component of the mission will first look at the size and shape of the impact crater made by DART. This will give us the first information about the composition of Didymoon, because different materials will react in different ways to the collision. Hera will also carry a suite of instruments to perform other analyses, allowing it to deduce the asteroid's mass, density and thermal properties. Only by gaining this information can we accurately translate the DART mission's achievements into what we should do if

"WE CAN CAUSE AN IMPACT NOT TO HAPPEN. WE HAVE THE TECHNOLOGY TO DO THIS, AND WE NOW WANT TO TEST IT"

A PLANET IN PERIL

Asteroids aren't the only space-based hazards that could put our lives in jeopardy...



SPACE DEBRIS

Although unlikely to cause a widespread threat to life on Earth, space debris is a huge concern. It poses a serious risk to orbiting satellites, and because we rely on those satellites for so many things related to communication and navigation, it threatens our way of life.

DANGER FACTOR: HIGH

SUPERNOVAE

Exploding stars pose a danger to life because of the torrent of high-energy radiation they would release. To be a risk to us, however, there would need to be a red supergiant star within 50 light-years of Earth. Luckily, no such stars are anywhere near that close.

DANGER FACTOR: NEGLIGIBLE

SOLAR STORMS

Giant releases of magnetic energy on the Sun can propel vast clouds of electrified gas towards us on Earth. These can seriously damage our technology such as satellites and power grids. A large solar storm could cause major disruption through sustained power blackouts and communications outages.

DANGER FACTOR: MODERATE TO HIGH

EVIL ALIENS

We've all seen the films where marauding aliens come to Earth and wreak havoc. In real life, however, astronomers see no evidence for alien technology, which would naturally give off some kind of detectable emission because... physics. So perhaps evil aliens simply don't exist.

DANGER FACTOR: LOW (PROBABLY?)

NASA/JOHNS HOPKINS, SCIENCE PHOTO LIBRARY, NASA GSFC X2, GETTY IMAGES, ESA

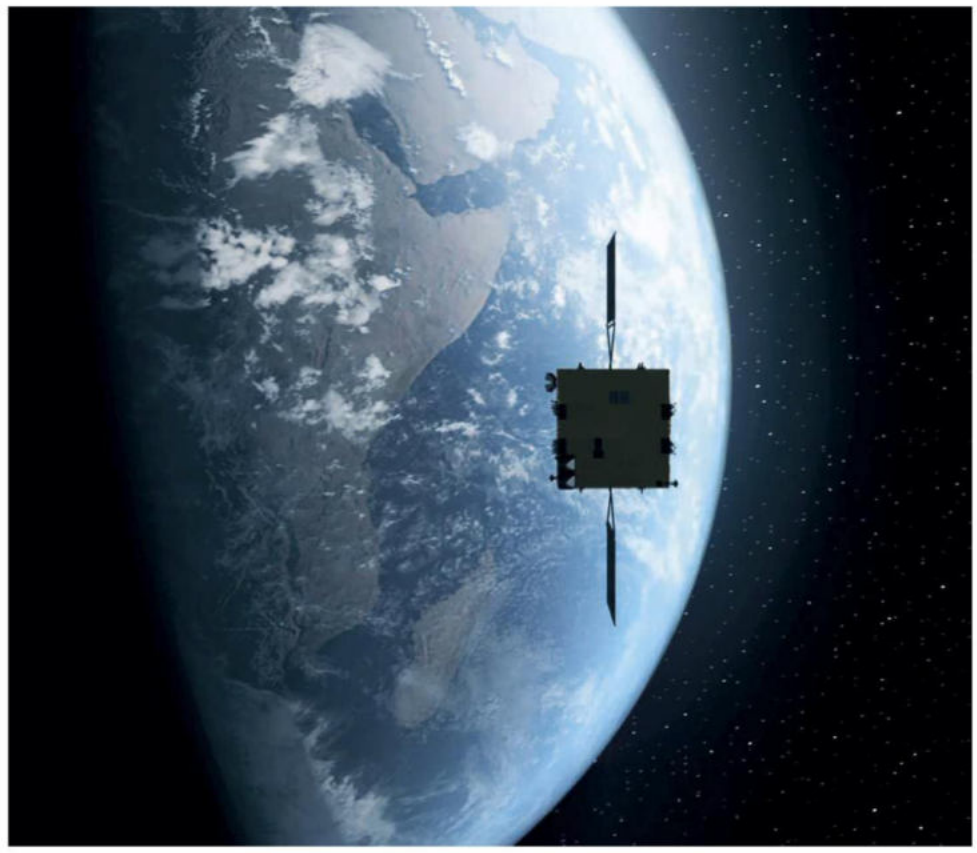
we see another asteroid heading for us in the future. "These properties will help us to simulate deflection impacts more accurately," says Carnelli. He imagines a future time in which a hazardous asteroid is spotted coming our way. It can be immediately studied to learn its properties and these numbers can be compared to those of Didymoon. "You put these numbers into the computer and it tells you exactly how hard to hit it to deflect it," says Carnelli.

In other words, Hera completes DART by making the mission a precise deflection test that can be widely applied to any incoming object we detect in this size range. But there is a big hurdle for the mission to cross: funding.

NASA's DART is fully funded. It's being built and will launch in two years' time. Hera needs €140m (£128m approx) from European science ministers this November to be built, and then an additional €160m (£146m approx) in three years' time to be launched and operated. The funding is not guaranteed. A previous version of the mission was rejected in 2016.

For Carnelli, who has been studying asteroid deflection tests at ESA since the early 2000s, this is something of a do-or-die moment. "In 2003-4, asteroid deflection was still quite fictional in terms of asteroid deflection techniques," he says. "I still remember when people were proposing to paint asteroids, or attach them to solar sails, or to anchor some ion propulsion systems. All of this has disappeared. There is a very well-established planetary defence community now. And as a community, we know what we want. We just need to get it done."

Because in real life, we won't have Bruce Willis to save us. **SF**



by **DR STUART CLARK** *(@DrStuClark)*

Stuart is an astronomer and science writer. His latest book is The Search for Earth's Twin *(£12.99, Quercus).*

SHOULD YOU UPGRADE YOUR BRAIN?

Words: LUCY MADDOX

Mind-machine interfaces have the potential to upgrade our intelligence and supercharge our thinking. But at what cost?

Would you have an IQ-boosting microchip implanted in your brain if you had the chance? What if everyone else around you did? Imagine your work colleagues outperforming you, and your friends having conversations you can't quite follow. Would you upgrade your brain then? Should you?

It sounds like science fiction, but it's not such an outlandish idea. Earlier this year, an announcement from tech entrepreneur Elon Musk's company Neuralink caught the attention of the world's media. A range of different ways to link brain signals and computers – brain-computer interfaces, or BCIs – already exist, but Neuralink has improved this technology using impressively small, super-thin, flexible micro-electrodes, which enable a tiny device to be implanted in the brain to read (and potentially write) neural signals. They have trialled this in monkeys, and seek to trial it in humans.

So far, research has focused on the many possible medical applications for BCIs, but Neuralink also wants to create a device that can be used by healthy people for brain improvement. Cognitive enhancement could be the future Botox. But although a tuned-up brain could expand human possibilities, some experts are already cautioning of the dangers that may lie ahead. Brain enhancement of healthy individuals is not yet possible, but Dr Davide Valeriani is one expert who thinks that it could become an option within his lifetime.

"All big companies are interested in jumping into brain-computer interfaces," explains Valeriani, a postdoctoral researcher in BCIs at Harvard Medical School in the US. He lists Amazon, Facebook and Microsoft, as well as agencies such as the US military. "If big companies work on this then we can push the research. They have more resources."

MIND MACHINES

As well as the technical challenges associated with implanting a chip in the brain, Valeriani points out that there are other, more intangible problems to solve. The benefits of BCIs in helping individuals who are paralysed or brain-damaged are clear to see, but the advantages for healthy individuals would have to be extra special to outweigh the risks of the invasive surgery, and overcome a range of ethical dilemmas. Potential problems include the possibility of 'brain-hacking' (a person or agency somehow taking control of the chip or accessing data), and ethical compromises if the technology is used experimentally in countries with a poor human rights record. In addition, the animal experiments needed to develop the technology are one thing when viewed in the context of helping paraplegia, and quite another when viewed in the context of souping up the brain.

So what are the potential benefits? Why would we want electrodes implanted in our brains? Valeriani is working on improving decision-making, especially decisions that might have a large negative impact ➤

ILLUSTRATION: ANDY POTTS

BRAIN COMPUTER INTERFACES: THE STORY SO FAR

ALAMY X2, SCIENCE PHOTO LIBRARY, RICK FRIEDMAN, URMC

ABOVE As of 2019, brain-computer interfaces have come a long way, but they're still some way off becoming unobtrusive

if we get them wrong, for example a doctor misdiagnosing a medical problem, or a soldier making a bad choice in a military situation.

"What I see as the advantage of BCIs is that you keep the human in the loop," says Valeriani. Rather than handing over all our decision-making to artificial intelligence (AI), BCIs could assist us with our dilemmas, helping to modulate and correct our inherent biases and blind spots. "If a human is assisted by a BCI and then there is another completely independent machine that makes a decision based on the same information, you can merge the two decisions together, and we showed recently that they work better together than each of them alone," says Valeriani.

Research is also advancing BCI-assisted communication. "BCIs are not reading thoughts," says Valeriani, "they're looking for patterns." Computers can be trained to recognise patterns of brain activity that occur when, for example, we're thinking about a certain object, or willing a particular body part to move. It's this technology that allows people to move prosthetic limbs with their thoughts. Getting better at this pattern recognition might eventually allow us to identify the specific contents of people's thoughts, therefore opening up a whole world of possibilities such as telepathic communication, being able to update our Facebook statuses with our minds, or drive our cars by thought. We're far from the required resolution yet, but the potential is there.

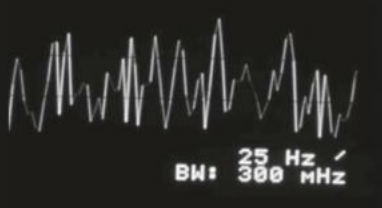
Another possibility is computer-based memory extension. We already treat our computers and smartphones as a kind of memory aid, using them to store our work, photos, calendars and conversations. What if BCIs could one day increase the amount of memory that is instantly available to our

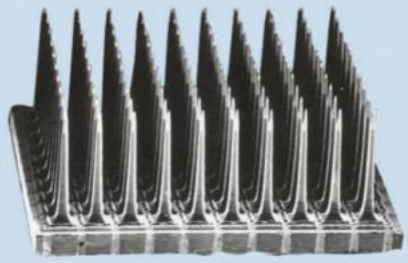
1973

The first brain-computer interface (BCI) is created by Jacques Vidal (below) at the University of California. He uses non-invasive electroencephalogram (EEG) recordings of brain activity to communicate with a computer.

1988

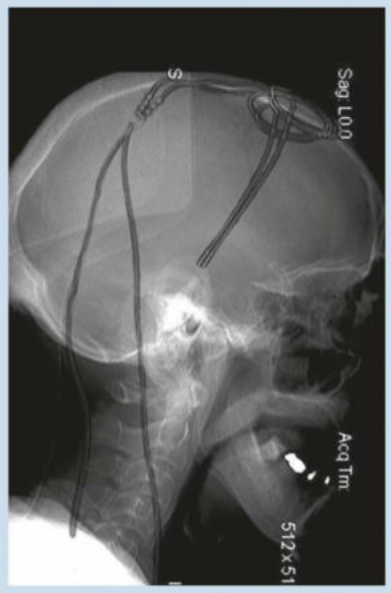
Researchers in the former Yugoslavia use EEG brain signals to control a physical object for the first time – issuing commands to a robot by simply opening and shutting their eyes.





1991

A 100-electrode device called the Utah Array (above) is invented by Richard A Normann. It can be implanted in the brain to stimulate brain cells, or to record their output to electronic circuitry.



1997

Deep brain stimulation, which involves implanting electrodes into the brain (above), is approved by the US Food and Drug Administration for the treatment of the tremors of Parkinson's disease.

2000

Researchers at Duke University, North Carolina, develop a BCI that can decode brain activity in monkeys and reproduce the monkeys' arm movements in a robot.

2005

Matthew Nagle (below) becomes the first person to control an artificial hand using thought. Paralysed from the neck down, Nagle also uses the brain-reading technology – developed by Massachusetts-based company Cyberkinetics – to play games, operate a TV and access emails.

2016

Another paralysed man, Nathan Copeland (above), is the first to be given a sense of touch through a mind-controlled robotic arm, thanks to a BCI developed at the University of Pittsburgh that stimulates the sensory region of the brain.

2019

Elon Musk (above) unveils Neuralink's plans for its advanced BCI technology, which involves using a specially built surgical robot to insert thousands of flexible, thread-like electrodes into the brain.

HOW IT WORKS:
NEURALINK

The tech behind Elon Musk's brain-reading machine

1. Neuralink's new 'n1' sensor fits into a case measuring 8mm in diameter and 4mm in height.

2. All of the components of the Neuralink are stacked inside the case and hermetically sealed.

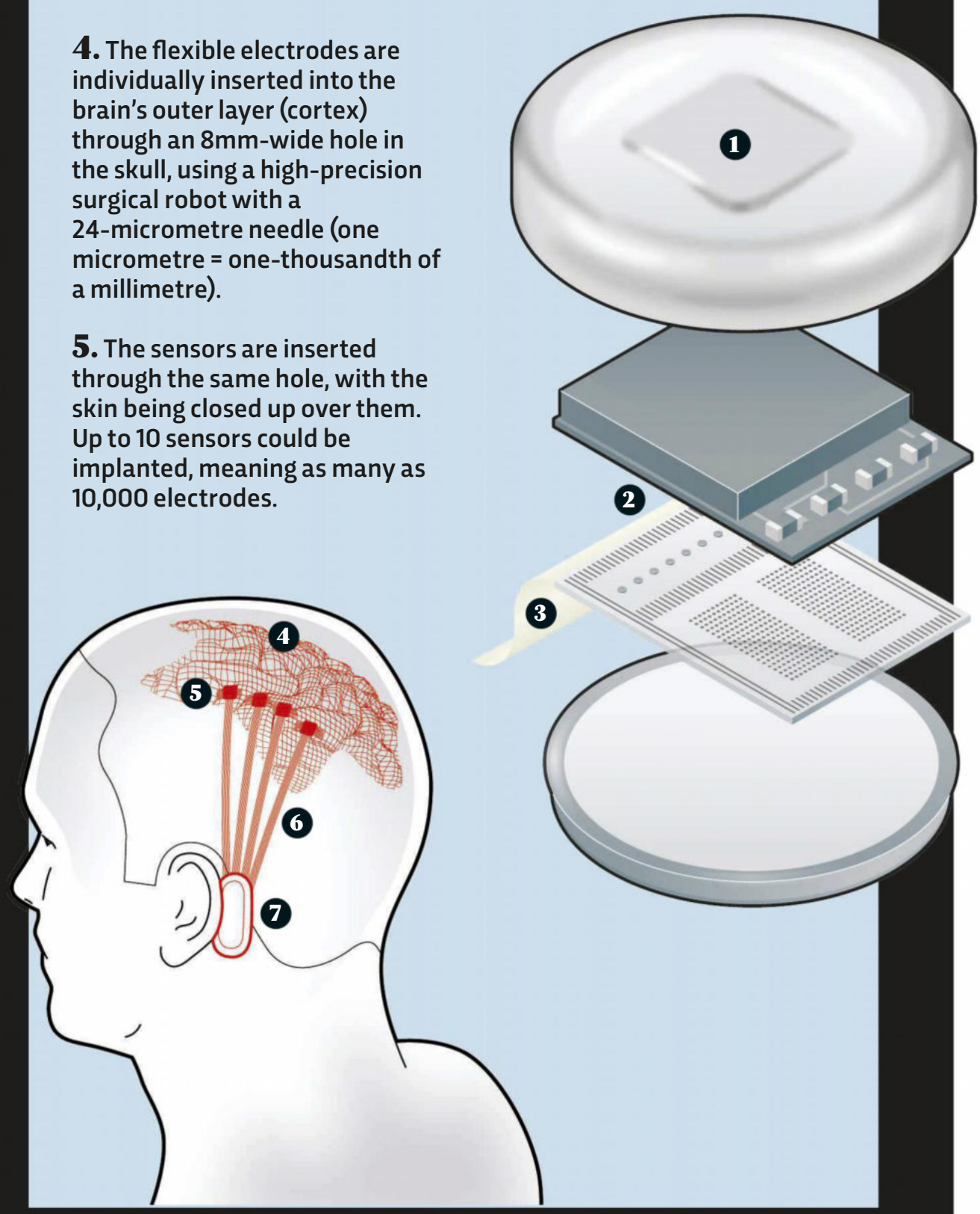
3. Each sensor is connected to 1,024 flexible, thread-like electrodes capable of reading and writing to nerve cells (neurons) in the brain. Each thread is about a tenth of the width of a human hair.

4. The flexible electrodes are individually inserted into the brain's outer layer (cortex) through an 8mm-wide hole in the skull, using a high-precision surgical robot with a 24-micrometre needle (one micrometre = one-thousandth of a millimetre).

5. The sensors are inserted through the same hole, with the skin being closed up over them. Up to 10 sensors could be implanted, meaning as many as 10,000 electrodes.

6. The sensors are connected to an induction coil beneath the skin behind the ear, via thin wires tunnelled under the scalp.

7. The induction coil connects through the skin to a wearable device called 'The Link', which sits behind the ear and communicates with the implanted sensors via Bluetooth.



brain, allowing us to store memories of everything we've ever experienced, and never forget a face or a name?

Last year, researchers led by Dr Robert Hampson at the Wake Forest School of Medicine, North Carolina, successfully improved people's short-term memory by directly stimulating brain cells in their hippocampus – an area of the brain involved in memory. The scientists recorded the pattern of brain cell activity during remembering, and then used the same pattern to stimulate the cells while a memory task was being carried out – increasing performance by over 35 per cent. The participants in this experiment were epilepsy patients who were already having electrodes implanted in order to monitor their seizures, but the scientists are hoping to develop this technology to help with dementia, and it may one day find its way into BCIs for healthy individuals, too.

Although the technology isn't there yet, Valeriani thinks that a removable device would be a better option for healthy individuals, so that it could be kept outside the body and switched off when necessary. "So if we don't want to use it, we don't have to… we'd be able to separate 'what is me' from 'what is technology'."

IDENTITY CRISIS

The question 'what is me? takes BCIs into the realm of philosophy. Dr Susan Schneider, a philosopher and cognitive scientist at the University of Connecticut, is interested in the links between future technology, the mind and the self.

"Imagine walking into a mind design centre of the future, like a cosmetic neurology centre, and seeing a menu in front of you with all these enhancements," she says. She imagines being able to reach the meditative states of a Zen master, or gain the musical abilities of Mozart – or even sculpt your personality.

"I understand the pull of all of this," says Schneider. "But if you decide you're going to purchase a bunch of

NEUROLINK ILLUSTRATION: ACUTE GRAPHICS

> "IF YOU PURCHASE A BUNCH OF THESE ENHANCEMENTS ... IS THE PERSON WHO EMERGES TRULY YOU?"

these enhancements ... is the person who emerges truly you?" She thinks there will come a point when a person replaces so much of their brain with artificial components that they've actually killed themselves without realising it.

This riffs on classic thought experiments. How much of our brain do we need to keep in order to be the same person? If we suddenly lose our memories, does this mean we're not us? What about if a brain injury affects our personality? What makes me 'me'?

THINKING AHEAD

University of Sussex neuroscientist Prof Anil Seth likes to think about the potential problems around BCIs in terms of a 'worry budget'. As we only have so much worry to go round, he argues, we should spend it on more immediate concerns related to our use of technology, such as social media algorithms, which influence what we see online and therefore our behaviour. In the realm of decision-making, he thinks we need to consider, now, who will be responsible if future AI helps us to make a bad decision.

He's not so worried about AI becoming conscious, or accidentally modifying ourselves out of existence. "I'm not sure I'd worry too much specifically about no longer being the same person," he says. "We are always changing who we are, even if we do not perceive this."

Seth is also concerned about equality. "We can get caught up in the technological and scientific excitement, but equality of access is important. We could start to see people who are developing and purchasing this stuff pull apart from the rest of the population. That's something that ought to keep people up at night."

Whatever we choose to spend our personal worry budgets on, BCI technology is advancing fast. Some transhumanists (who think technology should be used to enhance the human condition) have already implanted microchips in their bodies to act as door keys or credit cards. The technology to implant microchips in the brain, or perhaps a non-invasive, removable alternative, is not inconceivably far away.

Whatever happens next, Valeriani, Schneider and Seth agree that we need to keep the ethical and philosophical dilemmas in mind as the technology evolves. The answer to whether we should upgrade our brain relates to bigger 'shoulds' about fairness, responsibility and who we consider ourselves to be. Perhaps it also relates to what sort of people we *want* to be. Is it enough to want to be upgraded? Or should we be upgrading our social and ethical ambitions instead? **SF**

by **DR LUCY MADDOX**
(@lucy_maddox)
Lucy is a consultant clinical psychologist who writes about psychology and neuroscience.

Q&A

ALL YOUR QUESTIONS ANSWERED

THIS ISSUE'S EXPERTS

DR ALASTAIR GUNN
Astronomer, astrophysicist

ALEX FRANKLIN-CHEUNG
Environment/ climate expert

ALOM SHAHA
Science teacher, author

DR PETER J BENTLEY
Computer scientist, author

DR HILARY GUITE
Former GP, science writer

CHARLOTTE CORNEY
Zoo director, conservationist

DR HELEN SCALES
Oceans expert, science writer

DR CHRISTIAN JARRETT
Neuroscientist, science writer

DR EMMA DAVIES
Chemistry expert, science writer

LUIS VILLAZON
Science/tech writer

JULES HOWARD
Zoologist, science writer

PROF ROBERT MATTHEWS
Physicist, science writer

ANNA BRIGGS, PLYMOUTH

HOW FAR FROM EARTH COULD ALIENS DETECT OUR RADIO SIGNALS?

While commercial radio broadcasts began around 100 years ago, these early transmissions used frequencies that were either mopped up by the atmosphere or drowned out by radio emission from the Sun. In contrast, military radar transmissions set up during the Cold War to detect incoming ballistic missiles have the power and frequency characteristics to be detected over hundreds of light-years – and have already broadcast our existence to any aliens within around 60 light-years of the Earth. *RM*

GETTY IMAGES

JESSICA HOWARD, INVERNESS

WHAT WOULD HAVE HAPPENED IF WE'D CARRIED ON USING CFCs?

In the late 1970s, scientists noticed levels of ozone gas (O_3) dropping in the ozone layer, a region of the stratosphere some 15 to 30km above our heads. The ozone here absorbs most of the Sun's damaging ultraviolet (UV) radiation, shielding us from UVB and UVC rays. The culprit for the disappearing ozone? Chlorofluorocarbons (CFCs), which were used in fridges, aerosols and air conditioners. As CFCs entered the atmosphere, they released chlorine atoms which broke down ozone and allowed more UV radiation through.

As rates of ozone depletion accelerated, the international community sprang into action. Effective from 1989 and signed by 197 countries, the Montreal Protocol has now phased out 99 per cent of CFCs and other ozone-depleting chemicals, with ozone levels predicted to make a full recovery by the 2050s. Without this treaty, CFCs would have continued to rise, with disastrous consequences for life on our planet.

In humans, heightened exposure to UVB radiation would have triggered a surge in incidences of skin cancer and cataracts. According to one estimate, there would have been an extra two million cases of skin cancer worldwide by 2030. By 2065, UV radiation at the planet's surface would have reached three times its current strength, making any Sun exposure dangerous.

Overexposure to UVB radiation stunts the growth of many plants, and the resulting decline in agricultural productivity could have triggered food shortages. The radiation harms phytoplankton, too – the tiny organisms that form the basis of marine food webs – with untold consequences for wider ecosystems. CFCs are powerful greenhouse gases, and US researchers have calculated that there would have been an additional 2°C of global warming by 2070 if CFCs had been left unchecked. This would have fuelled extreme weather such as floods, droughts, hurricanes and heatwaves.

Fortunately, this disaster scenario was averted, and today the Montreal Protocol is often heralded as the most successful piece of environmental legislation in history. ***AFC***

HENRY BUTLER, CANTERBURY

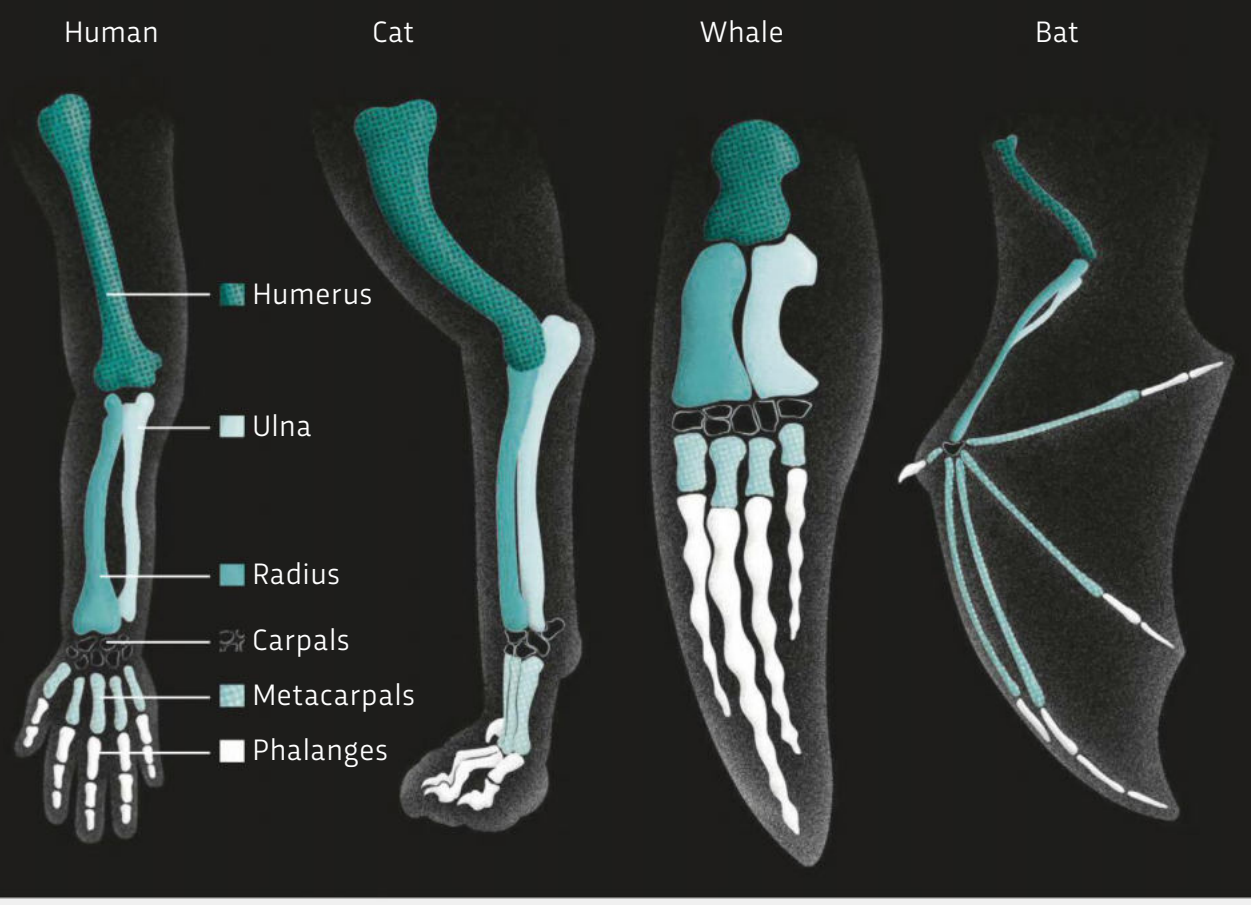
WHY DO MILLIPEDES HAVE SO MANY LEGS?

Though no known millipede species has 1,000 legs, common species of this burrowing arthropod have between 40 and 400 legs – more than enough to move the millipede forwards with impressive heft. Like an army of tiny soldiers running a giant battering ram into a wall, this adaptation allows the millipede's head to be forced into the cracks between lumps of soil where the most delicious leaf matter often resides. These crevices also offer excellent protection from predators. *JH*

EDWARD SEYMOUR, HOVE

ARE HUMAN AND ANIMAL BONES THE SAME?

Humans and other mammals share the same distant ancestors, so our bones are almost identical to theirs in form and function. The bones in your hand have the same layout as those in bat wings and in the fins of whales, for instance. What differs most between species, however, is the thickness, size and density of minerals that provide strength to bones. This is what scientists are most interested in when trying to determine the origin of mysterious bones. Even today, mistaken identifications of human bones from animal remains can occur. To the untrained eye, the bones within the paw of a bear, for instance, look very similar to the bones within the human hand. *JH*



GEEK_KID, VIA TWITTER

DOES EATING BLUE CHEESE CONTRIBUTE TO ANTIBIOTIC RESISTANCE?

Discovered by Alexander Fleming in 1928, the antibiotic properties of penicillin, derived from a species of *Penicillium* fungus, are still widely used today, though many bacteria have become resistant to the drug over time.

Antibiotic resistance occurs when bacteria are regularly exposed to doses of antibiotic that are not quite strong enough to kill all the bacteria. In these situations, the antibiotics only kill off the weakest bacteria, which leaves the slightly stronger ones to multiply and spread their more resistant genes. Blue cheese does contain cultures of *Penicillium* mould. You might therefore think that eating too much blue cheese could have a similar effect to antibiotic resistance, by overexposing the bacteria in your body to *Penicillium*. However, the strains of *Penicillium* that are used in cheesemaking are different to the ones in the drug, and don't have any significant antibiotic properties to begin with. Besides, they are destroyed by your stomach acid anyway. ***LV***

SIMON BARTLETT, VIA EMAIL

IS 'SNAKEBITE' JUST A MIXTURE OF LAGER AND CIDER, OR A CHEMICAL REACTION BETWEEN THE TWO?

There's no chemical reaction, because the main ingredients are the same: water, alcohol and carbohydrates. So the drinks just mix together. Despite the fact that some bars refuse to sell snakebite, the beverage is actually no more deadly than a pint of beer or cider alone – both drinks tend to have a similar alcohol content, so mixing them just produces a drink of a similar strength. The feeling of getting drunk quicker is likely to be purely psychological. ***ED***

GETTY IMAGES X4, ALAMY X2 ILLUSTRATION: DAN BRIGHT

KEITH ANDERSON, BRADFORD

DO FISH FEEL PAIN?

It's an old adage that fish don't feel pain. Their brains are too small and simple – or so the story goes. But evidence is stacking up to the contrary. In 2003, researchers at the Roslin Institute near Edinburgh discovered sensory nerves in bony fish that allow them to detect pain in a similar way to birds and mammals, linking their skin and other areas of the body to the brain. The same team went on to find that, when injected in the lips with mild acid or bee stings, rainbow trout rocked their heads and rubbed their lips against the aquarium tank. Given painkillers, the trout behaved normally again. Many other studies reveal aspects of fish suffering, including in cramped fish farms where some salmon stop feeding and show signs of depression, such as high levels of the stress hormone cortisol. ***HS***

HIDDEN FIGURES

ABU YŪSUF YA'QŪB IBN 'ISHĀQ AS-SABBĀH AL-KINDĪ

THE MAN WHO BROUGHT SCIENCE OUT OF THE DARK AGES

For centuries following the collapse of the Roman Empire in the 5th Century, texts by key thinkers from Ancient Greece, India and elsewhere became lost to the world. The texts still existed physically, but during the Dark Ages very few scholars could read them in their original language. That changed in the 9th Century, with the work of the Arabic polymath Al-Kindi.

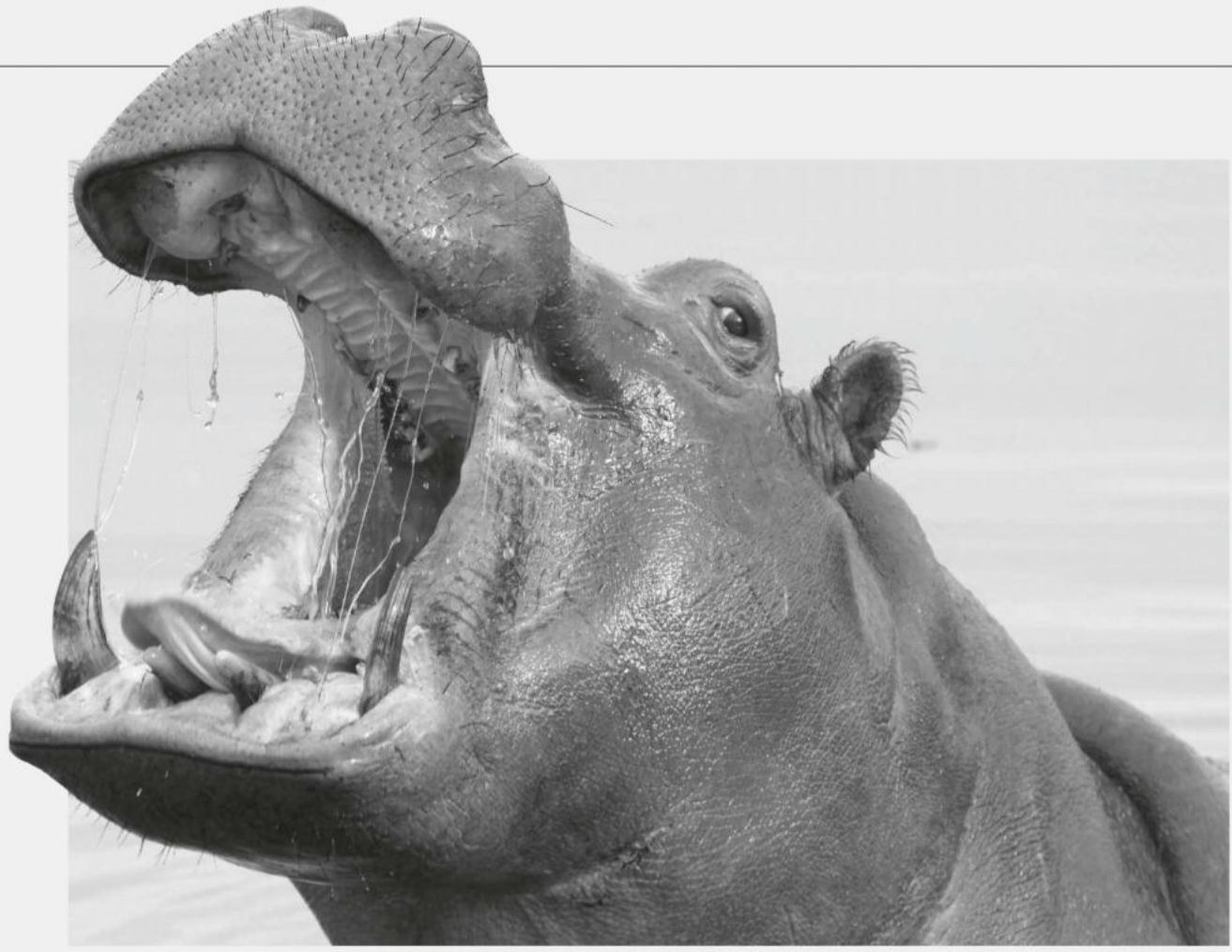
Born around 800 in what is now the Iraqi city of Kufa, Al-Kindi became the leading scholar at the House of Wisdom, a grand library created by the ruling caliphs of Baghdad. He led a team of translators working on ancient texts by the likes of Hippocrates and Aristotle. Over the decades, manuscripts on everything from astronomy to medicine and logic were brought back into circulation by being rewritten in contemporary Arabic, and in a newly available format: paper, imported from China. A brilliant academic, Al-Kindi also contributed his own insights in fields as diverse as pharmacology and code-breaking. He is regarded as one of the greatest scientific polymaths of all time. ***RM***

OLD WIVES' TALES...

CHEWING GUM TAKES SEVEN YEARS TO DIGEST

The digestive system isn't like an in-tray, where everything remains until fully processed: it's more like a conveyor belt. Whatever you eat moves through your intestines at roughly the same speed, and anything that doesn't get broken down and absorbed into your bloodstream passes out the other end. This usually takes one to three days. Chewing gum can't stick to the wet intestinal wall, so a single piece of swallowed gum normally gets swept along with everything else. There are a few cases in the medical literature of small children swallowing many pieces of gum that formed a lump too large to pass. But this quickly caused severe constipation and pain, and needed surgery to remove.

But supposing some gum did somehow get trapped, would it take seven years to digest? Chewing gum is 70 to 85 per cent sweeteners, flavourings and starch, all of which are digestible. But the remaining 15 to 30 per cent is a blend of synthetic polymers, often including butyl rubber. This rubber is also used to make the seals on chemistry lab flasks, and is rated as suitable for storing hydrochloric acid that is 30 times more concentrated than the acid in your stomach. So if you could somehow withstand the severe constipation, the gum would likely last at least seven years. ***LV***



EMRE YORGANCIGIL, ISTANBUL, TURKEY

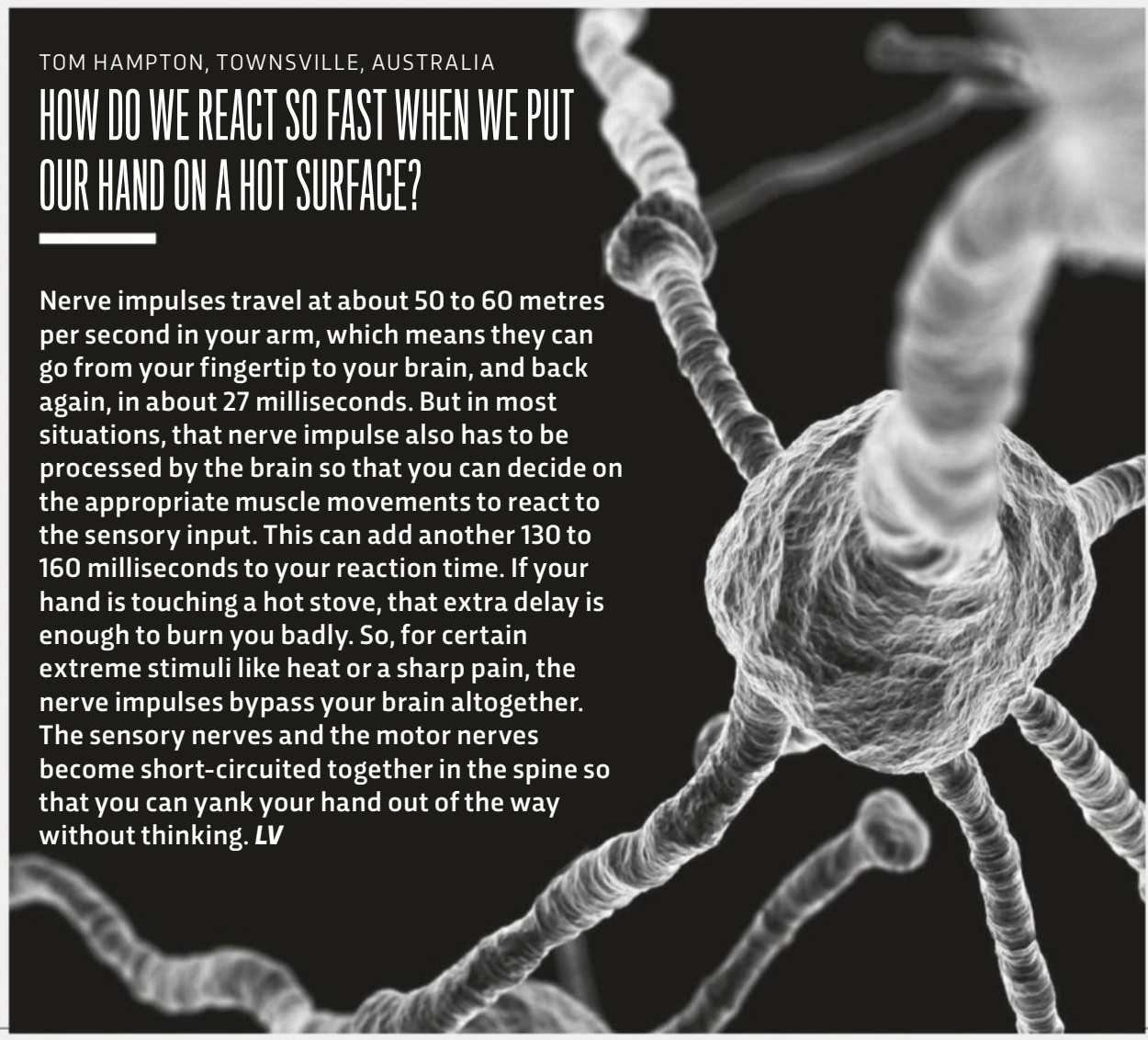
WHY CAN'T WE CLOSE OUR EARS LIKE WE CAN CLOSE OUR EYES?

We have evolved eyelids to protect our eyes from drying out or getting scratched. When you are sleeping, it is dark anyway, so there's not much point in your eyes being open. But your ears have evolved as an important early warning mechanism, allowing you to wake up if, say, there's a tiger growling in the undergrowth. Some animals, including seals, otters and hippos, can close their ears, but this is to keep water out while swimming. ***LV***

TOM HAMPTON, TOWNSVILLE, AUSTRALIA

HOW DO WE REACT SO FAST WHEN WE PUT OUR HAND ON A HOT SURFACE?

Nerve impulses travel at about 50 to 60 metres per second in your arm, which means they can go from your fingertip to your brain, and back again, in about 27 milliseconds. But in most situations, that nerve impulse also has to be processed by the brain so that you can decide on the appropriate muscle movements to react to the sensory input. This can add another 130 to 160 milliseconds to your reaction time. If your hand is touching a hot stove, that extra delay is enough to burn you badly. So, for certain extreme stimuli like heat or a sharp pain, the nerve impulses bypass your brain altogether. The sensory nerves and the motor nerves become short-circuited together in the spine so that you can yank your hand out of the way without thinking. ***LV***



DIY SCIENCE

SMOKE RING CANNON

WHAT YOU'LL NEED
- One-litre plastic bottle
- Scissors
- Rubber balloon
- Sticky tape
- Incense stick
- Lighter

WARNING
This experiment involves a naked flame, so should be carried out with adult supervision

WHAT TO DO

1. Use scissors to cut off the bottom third of the plastic bottle.

2. Cut the balloon at the base of the neck. Discard the neck and keep the main round section.

3. Stretch the balloon over the open bottom of the bottle, so that it forms a tight 'skin'.

4. Secure the balloon to the sides of the bottle with sticky tape.

5. Light an incense stick.

6. Hold the open neck of the bottle directly above the burning incense stick until the bottle is full of smoke.

7. To make smoke rings, tap or poke the balloon skin with your fingers. Varying how hard you tap or poke will give different results.

WHAT'S HAPPENING

Tapping or poking the balloon skin exerts a force on the smoky air in the bottle, making a puff of smoke move out of the hole in the neck.

The smoke on the outside of the puff experiences more friction than the smoke in the middle, because it's in contact with the edges of the bottleneck, and the air outside the bottle, as it emerges. This results in the smoke on the outside moving slower, then it starts spinning as it's simultaneously dragged forwards by the faster smoke in the middle and pulled backwards by the frictional forces. The spinning smoke forms a doughnut shape, also known as a 'toroidal vortex'.

The smoke in the ring stays together because of the law of the conservation of angular momentum, which means that spinning objects tend to stay spinning unless an external force is applied. If the smoke wasn't spinning, it would disperse as smoke ordinarily does when it mixes with air. ***AS***

GETTY IMAGES X2 ILLUSTRATION: DAN BRIGHT

DEAR DOCTOR...

DELICATE ISSUES DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I LOVE THE TASTE OF CURRY, BUT I CAN'T STAND THE BURN. CAN I BUILD UP A TOLERANCE TO IT?

The heat in a curry comes from the capsaicin compound in chilli peppers. This causes the pain receptors in your mouth to release a molecule called PIP2, which creates a burning sensation, even though there's no actual tissue damage. Your genes control how tightly PIP2 is bound to the pain receptors, which in turn determines how sensitive you are to the spice, but repeated exposure to chilli will reduce the effect quite quickly. A 1991 study at Yale University found that daily exposure over six days was enough to significantly reduce the perceived burn. So it's possible to build up a tolerance, but even true 'chilli heads' will always feel the heat from a vindaloo – they just relish the extreme sensation. ***LV***

I'M ADDICTED TO THE GYM, BUT I HAVE A COLD. CAN I STILL EXERCISE?

A good rule of thumb is the 'above-the-neck test', which says that if your cold symptoms are all in your head – such as a runny nose, sneezing or a sore throat – then it's safe to do some light to moderate exercise. Last year, health scientists at the University of Bath published a paper arguing that even vigorous exercise is okay, citing evidence that it can boost immune system functioning. Take it slowly, though, and tone down your session if you're feeling weak or uncomfortable. And if you have below-the-neck symptoms such as a high temperature or chest congestion, it's best to rest up completely, as exercising will raise your temperature even higher and stress your body, leaving you feeling rotten. ***HG***

I'VE BROKEN UP WITH MY EX. WHY IS LISTENING TO SAD SONGS MAKING ME FEEL BETTER?

You're far from alone. Surveys have shown that many of us like listening to sad music when we're feeling down. In fact, the tendency is strongest in people who are clinically depressed. It seems paradoxical – surely we'd be better off listening to jolly music – but when we're in a low mood, hearing a jingly track like *Happy* by Pharrell Williams can irritate us and accentuate our sense of isolation. In contrast, listening to sad music can help us to feel like we're not suffering alone. In research by the University of Limerick published in 2013, people talked about sad music being like a friend and triggering a sense of shared suffering (after all, as REM put it, *Everybody Hurts*). The participants also mentioned how sad music could trigger memories of loved ones, often making them feel better. This year, a team at the University of Florida found that even clinically depressed people feel happier and calmer after listening to doleful ditties – which somewhat disproves the theory that depressed people listen to sad music in order to exaggerate or perpetuate their low mood. ***CJ***

LAURIE WALKER, GUERNSEY

CAN ANYTHING BE DONE TO STOP CAR HEADLIGHTS BLINDING ME?

The glare from headlights causes accidents, and the problem is getting worse as bulbs get brighter. One way to cut out glare is with a polarising filter that only lets light through that travels in a single direction, cutting out all the other light waves wiggling in random directions. Back in the 1930s, the ingenious idea of using polarised headlights and a polarising filter in windscreens was suggested. Unfortunately, because of regulations, costs and the fact that polarising filters cut out too much light, the system was never introduced. Instead, the dimming rearview mirror was created, which can be flipped between a normal and dim reflection. Today, automatic dimming mirrors are available, as well as special polarised driving glasses, which both help to cut down glare. ***PB***

Deep-sea invertebrates, like this sea cucumber, could be good candidates to live on Jupiter's moon Europa

ANDREW CIREL, CORSHAM

COULD WE GENETICALLY MODIFY AN ANIMAL SO THAT IT COULD LIVE UNAIDED ON ANOTHER PLANET OR MOON?

There may already be microbes on Earth that could survive on Mars. Bacteria from the Dead Sea and the Arctic tundra have been shown to survive in a simulated Martian atmosphere. Venus would be trickier, even in its cooler upper atmosphere, because this planet has no ice or water. Alien life might have its own completely different biochemistry, but we couldn't genetically engineer it, because DNA molecules themselves require water.

For more complex, multicellular life, the lack of atmospheric oxygen on Mars would probably rule out this planet. Earth organisms that don't need oxygen are almost all single-celled because anaerobic metabolisms produce much less energy. But Jupiter's moon Europa has a liquid water ocean underneath its icy crust, and in 2009, researchers at the University of Arizona suggested that there might be oxygen too. How survivable this ocean is for Earth life will depend on what other toxins and nutrients are dissolved in it. Deep-sea fish and invertebrates would be good colonisation candidates, though, and genetic engineering might be useful to give them improved cold and pressure resistance. ***LV***

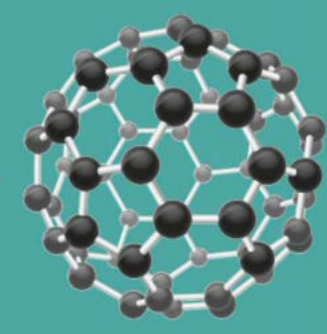
SAMUEL MURPHY, NOTTINGHAM

WHAT PROPELS THE 'SAILING STONES' ACROSS THE CALIFORNIAN DESERT?

Reports of rocks apparently moving across dry lakebeds in Death Valley, California, have been circulating for over a century. With some 'sailing stones' weighing over 300kg and leaving trails hundreds of metres long, scientists have long struggled to find a plausible explanation. That changed in 2014, when researchers led by Richard Norris at Scripps Institution of Oceanography showed that during the winter, rain turns to ice on the lakebeds, which then cracks during the daytime, forming large panels. These sometimes catch the wind, lift up and start moving – shoving even large boulders ahead of them across the soft mud. But conditions must be just right: if the ice is too thick, it doesn't break into panels; too thin, and it can't shove the rocks. ***RM***

WHAT CONNECTS THE HUBBLE TELESCOPE AND CORNWALL?

1. The Hubble Space Telescope was used to detect the largest electrically-charged molecule found so far in the interstellar medium of deep space. The molecules form hollow spheres, called 'buckyballs'.

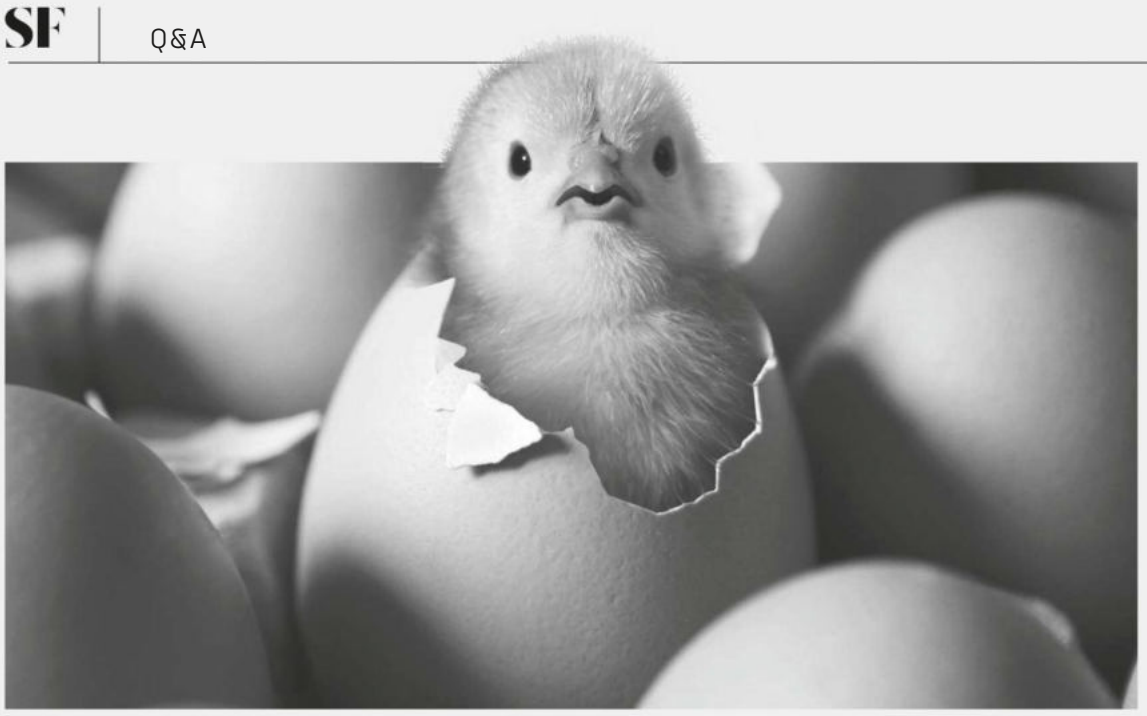


2. Buckyballs are a form of carbon, like diamond or graphite. Properly known as buckminsterfullerene, the molecule consists of 60 carbon atoms bonded together into a shape that resembles a

3. They are named after the American futurist and architect Robert Buckminster Fuller. In the 1940s he popularised the use of geodesic domes. These are enclosed structures, made up of triangular elements.

4. Geodesic domes are lightweight, strong, and enclose a large volume, making them the ideal design for the two huge greenhouses at Cornwall's iconic Eden Project, built in 2000.

ALAMY, GETTY IMAGES X4, DEEP SEA PHOTOGRAPHY ILLUSTRATIONS: DAN BRIGHT



TERESA HENDERSON, BLACKPOOL

IS IT POSSIBLE TO HATCH A CHICK FROM A SUPERMARKET EGG?

It's unlikely, but not impossible. Most commercial egg farms have strictly all-female flocks because male chickens aren't needed for egg production and aren't suitable for meat either (chickens raised for meat are a different breed). Without a rooster in the flock, the eggs will never be fertilised and can't develop into a chicken embryo. With other poultry species though, such as quail or duck, the males and females aren't segregated so strictly, and ducks can also come into contact with wild males and mate with them. There have been a few reported cases of supermarket duck and quail eggs being successfully incubated. ***LV***

EVERETT LOWENSTEIN, PORTLAND, USA

WHY IS IT BETTER TO STORE WINE HORIZONTALLY?

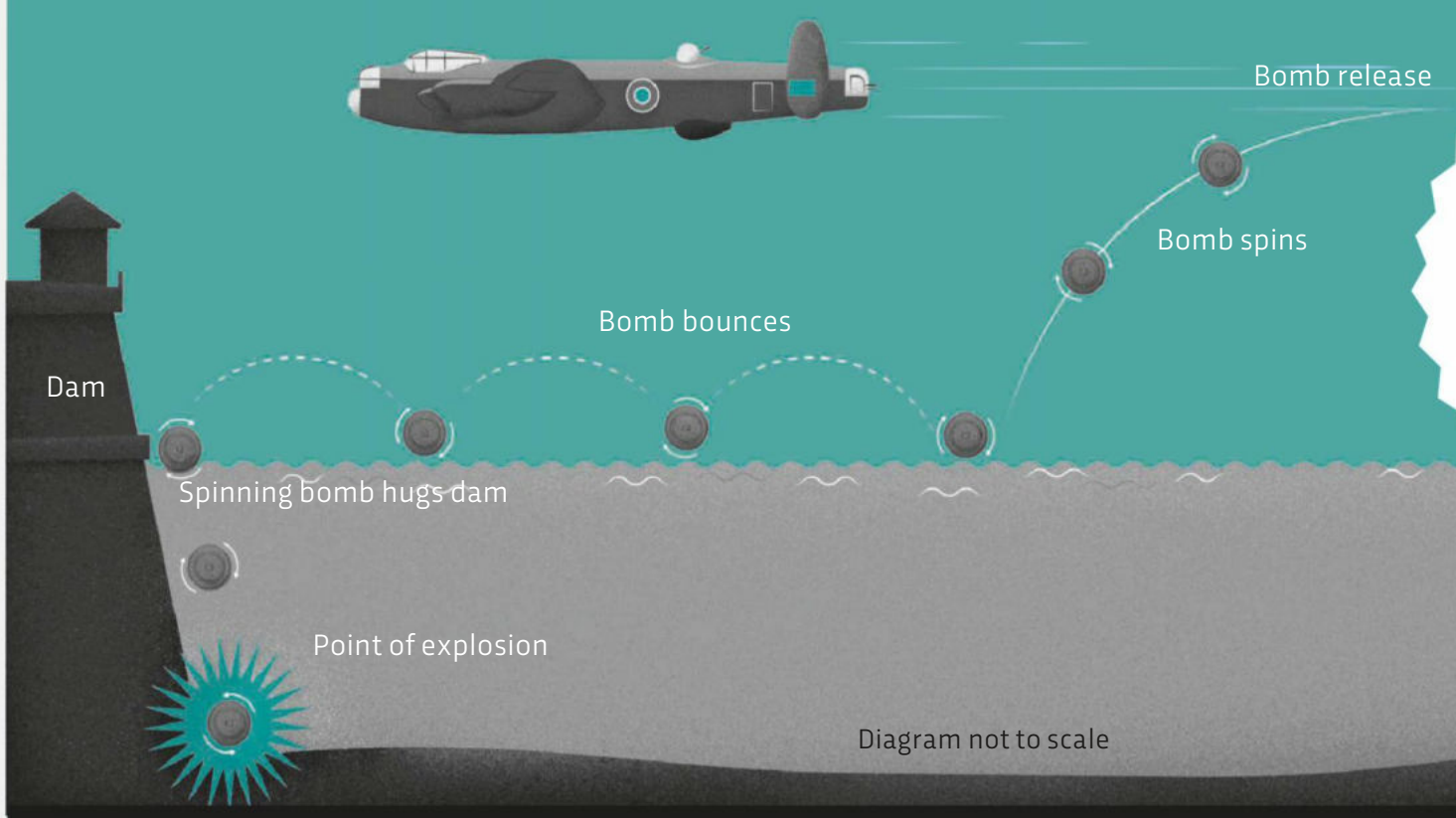
A horizontal bottle keeps the cork moist, so it doesn't dry out and shrink. At least that's the theory, but the science says otherwise. The air gap in a wine bottle has almost 100 per cent humidity, so the cork will never dry out as long as there is wine in the bottle. In 2005, the Australian Wine Research Institute tested this and found that the orientation of the bottle makes little difference to the wine's keeping qualities. ***LV***

QUESTION OF THE MONTH

ABBEY-LEIGH THOMPSON, LEEDS

HOW DID THE BOUNCING BOMB WORK?

There's some nifty physics behind the dam-busting bombs that were used by the British in WWII. Just like skipping stones, to make a bomb bounce off water you need to have enough speed and a perfect angle (about 7° in the case of the bomb). If you get these just right, conservation of momentum means that the water pushes back on the bomb and kicks it up in the air. For multiple bounces, the magic ingredient is spin. Spin the bomb and you stabilise its motion, like a frisbee or a gyroscope. The designers of the bouncing bomb made use of these principles, with the aim of saving the British bombers the tricky task of hitting a German dam bang on target. The cylindrical bombs were spun on launch, making them bounce several times, and as the bombs completed their final bounce, the spin even made them sink in a curved trajectory towards the dam. *PB*



WINNER

Abbey-Leigh wins a Chronomics epigenetics test kit, worth £179. After taking a saliva sample, Chronomics can reveal epigenetic insights, like biological age (how old the body truly is at DNA level), metabolic state (the most accurate indication of metabolic health), and exposures, such as the effects of passive smoke exposure on the body. **chronomics.com**

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM** OR TWEET US **@SCIENCEFOCUSQA**

GETTY IMAGES X3, FLPA ILLUSTRATIONS: DAN BRIGHT

ANNA DACA (LEICESTER) AND CALVIN TOMSIC (EVERETT, WASHINGTON, USA)

WHY DO CLOTHES GET DARKER WHEN WET?

As water is transparent, it seems odd that it makes clothes look darker. After all, it doesn't have that effect on, say, a hard plastic surface. Surprisingly, the science behind the phenomenon was only fully investigated around 30 years ago. Physicists John Lekner and Michael Dorf at the Victoria University of Wellington, New Zealand, showed that the darkening effect is the result of fabric being both rough and absorbent. When light strikes any surface, some of it is reflected back into our eyes. But damp clothes have a thin layer of water on their surface (held in place by the material's roughness), which leads to more of the reflected light rays being bent – 'refracted' – off-course. Some of the light also gets reflected back into the film of water, or scattered off the tiny water-filled holes in the fabric. The combined effect is a reduction in the amount of light reaching our eyes, which makes the fabric look darker. ***RM***

FATIMA, MANCHESTER

WHY IS THE MOON SOMETIMES VISIBLE DURING THE DAY?

In fact, the Moon is visible in daylight almost every day. The Earth's daily revolution on its axis means that the Moon is actually above the horizon for about 12 hours out of every 24. Usually, some portion of that time will be during daylight – you just need to look carefully, because its brightness is so much less than the Sun's. The only times you won't be able to see it during the day are near a new Moon, when it is positioned too close to the Sun in the sky to be seen, and near a full Moon, when it rises at sunset and sets at sunrise, so is only visible during the hours of darkness. ***AGu***

40

The percentage by which giraffe numbers have fallen in Africa over the last 30 years. In response to this, the animals and their body parts are now regulated under the Convention on International Trade in Endangered Species (CITES).

NATURE'S WEIRDEST CREATURES...

THE PINK FAIRY ARMADILLO

The pink fairy armadillo is mostly an apt name. After all, this is a species that spends most of its time in a subterranean neverland and whose pink armour, sitting atop silky white fur, gives it an almost magical charm. However, it also has some rather unfairy-like qualities. Fairies, for instance, do not have robust digging claws. And fairies do not use their enormous bottoms to firm up the soil as they dig to strengthen the walls of their tunnels.

This species of armadillo is found only in the deserts and scrublands of central Argentina. To limit the likelihood of heat exhaustion during the warm season, it uses its leathery shell as a cooling aid. By pumping this thin layer of armour with blood, the pink fairy armadillo can flush away heat from its body's core. This is an organism that doesn't spare its blushes. It depends upon them for survival.

Like all fairies, the pink armadillo is hard to see. The only time these animals surface is when heavy rain forces them out of their burrows, often into the mouths of introduced predators such as domestic cats and dogs. The species is likely to be declining in the wild, so this is one fairy that's in need of a godmother. ***JH***

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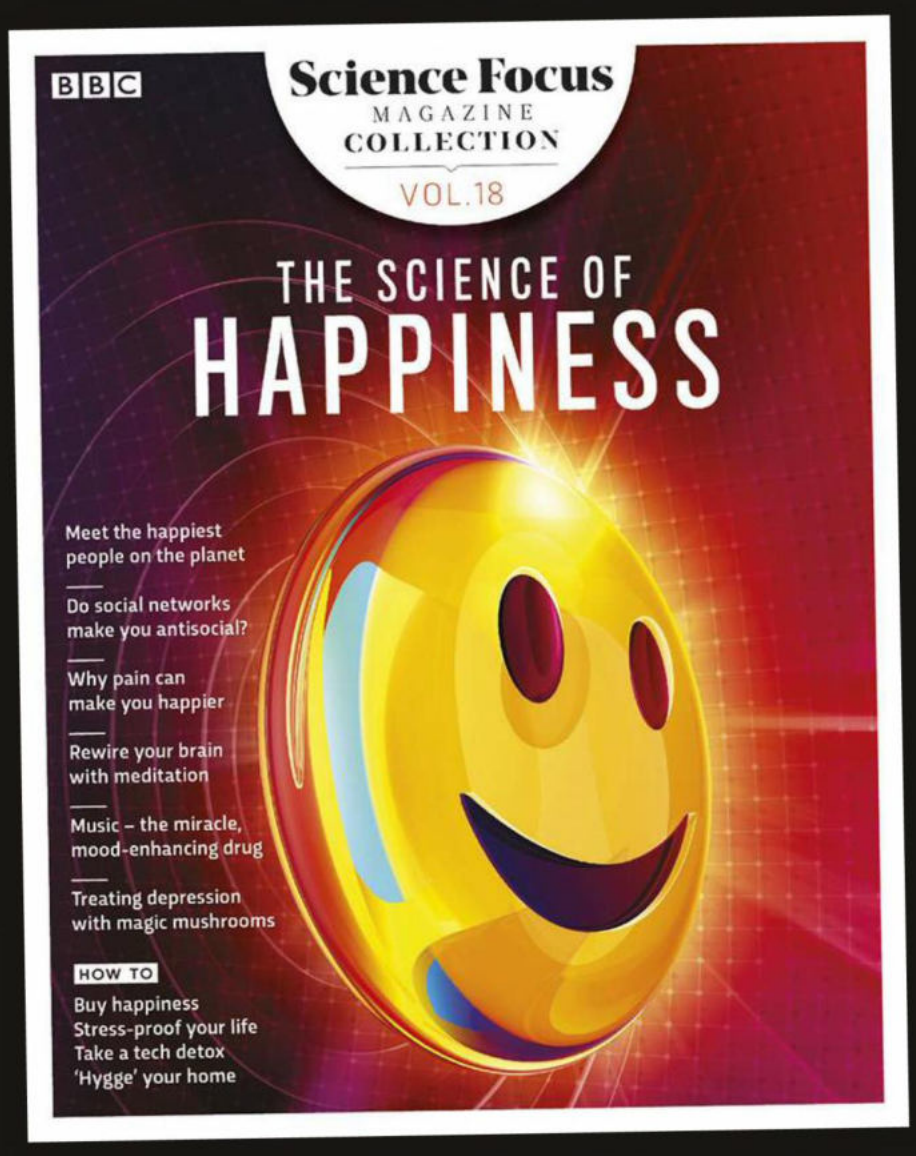
THE SCIENCE OF HAPPINESS



With hectic working days, demanding families and busy social lives, it can be hard to take time out for yourself. Yet scientists are recognising how important it is to look after your mental health and well-being, so you feel less stressed and happier.

IN THIS SPECIAL EDITION...

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- Discover how mindfulness alters your mind
- Get top tips from experts on how to be happy
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RADAR

WHAT'S LIGHTING UP OUR ANTENNA THIS MONTH

NASA, JASON PERRY, GETTY IMAGES, OSBORNE & HOLLIS, ROYAL SOCIETY COLLECTIONS

1. Capital feats
The new Science City galllery at the Science Museum charts London's evolution from 1550 to 1800. It features objects such as Sir Isaac Newton's reflecting telescope and King George III's own scientific instruments.
From 12 September
sciencemuseum.org.uk

2. Astro-night
For World Space Week, the National Space Centre has curated an evening of talks, demos and shows. The programme includes a talk from an X-ray astronomer, stargazing and a VR exoplanet experience.
5 October
bit.ly/space_lates

3. Orangutan on screen
Touring the UK this month is the Wilderland Film Festival, showcasing short nature and wildlife films from independent makers across the world. The festival's founders will introduce each film live on stage.
wilderlandfestival.com

4. It's our Earth
Earth Science Week is an annual celebration of all things geology. This year's events include walks, talks, workshops and open days across the UK and Ireland to show that geology is for everyone.
12–20 October,
www.geolsoc.org.uk

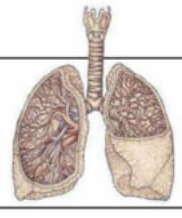
5. Practically impractical
From the creator of webcomic *xkcd* comes a self-help book with a twist. Randall Munroe offers absurd solutions to life's problems, with all the wit and humour that he is known for.
How To
£16.99, John Murray

6. Stellar snaps
Visit the National Maritime Museum this month to see images from the 2019 Insight Investment Astronomy Photographer of the Year prize. The exhibition features this year's shortlist and winners.
Until April 2020
rmg.co.uk

World Space Week launched in 1999, making this year its **20th anniversary** p90

World Space Week OCTOBER 4-10

10,000



The number of litres of air that each of us breathes every day. We learnt this after reading *Anatomicum*. p94

Profile

A SPACE FOR ALL

AHEAD OF WORLD SPACE WEEK, LEADING BRITISH SPACE SCIENTIST PROF MONICA GRADY TALKS TO US ABOUT THE NEXT GENERATION OF STEM PROFESSIONALS AND THE FUTURE OF SPACE EXPLORATION

Badges on the jacket of European Space Agency astronaut Jean-Francois Clervoy

WHEN DID YOU FIRST DECIDE TO PURSUE IN PLANETARY AND SPACE SCIENCE?

I did geology and chemistry for my first degree, which I really enjoyed. But I had no clue what I wanted to do – I just knew I didn't want to go into sales or anything like that. This was 1979, the internet hadn't been invented and it wasn't so easy to find out about the range of jobs available, so I decided I'd better stay on and do research.

Then I saw this advert for a PhD, for somebody to work on lunar samples and meteorites, and thought, "That sounds pretty interesting." I'd done a module in my final year about the Moon and lunar rocks. I'd seen them under the microscope, and they were fascinating. It just went on from there.

WHAT DOES IT TAKE FOR SOMEONE TO BECOME A SPACE SCIENTIST?

You've got to love it. That's a quality you need for any career, I think. You've got to enjoy what you're doing, because then you'll do it not just for the salary but for the enjoyment, for the people you meet and the things you're learning. Then it's not a pain to get out of bed in the mornings.

"I think it would be fantastic if we had a day when we switched space off, so people realised how much we rely on space and space technology"

LACK OF DIVERSITY IS A WIDER ISSUE IN STEM. WHAT DO WE NEED TO DO TO ENCOURAGE MORE PEOPLE INTO THE SPACE INDUSTRY?

This year, there were more women going on to science courses at university after A-Levels than men. But if you took out the biological and medical sciences, there were many, many more men going in than women. So it's getting over the idea that women can't or shouldn't do physical sciences.

World Space Week OCTOBER 4-10

WORLD SPACE WEEK

4 10 OCTOBER

WORLDSPACEWEEK.ORG

A lot of it is computer-aided design, really high-quality, high-precision engineering. It's the sort of thing that women, with their eye for detail, are really, really good at. You see people going into *The Great British Bake-Off* and doing these really elaborate cake designs… those skills are so important in the space industry. The creativity, the precision, the eye for detail.

WORLD SPACE WEEK WAS ORIGINALLY LAUNCHED TO 'CELEBRATE THE CONTRIBUTIONS OF SPACE SCIENCE AND TECHNOLOGY TO THE BETTERMENT OF THE HUMAN CONDITION'. SO WHAT HAS BENEFITED US THE MOST?

The benefits are a bit intangible, really. People talk about the 'spin-offs' from the Apollo programme being non-stick frying pans and stuff like that, but there are so many other technological benefits that have come from space exploration that people don't even realise.

I think it would be fantastic if we had a day when we switched space off, so people realised how much we rely on space and space technology. It's where all our satellites are orbiting. So, if you said okay, no orbiting satellites – that means no television, no weather forecasting, no bank transfers. The financial market would crumble. It would be utter chaos if those satellites were wiped out.

THIS YEAR'S THEME IS 'THE MOON, GATEWAY TO THE STARS'. WHAT RELATIONSHIP HAVE YOU HAD WITH OUR MOON OVER THE COURSE OF YOUR CAREER?

Distant! *[laughs]* It's a long way away. I have analysed lunar samples throughout the course of my career, and I've handled lunar samples – I've even helped find one or two in Antarctica when I was there collecting meteorites.

To understand the Moon is a very important part of understanding the wider Solar System and the Earth. It's interesting to see how stories change about how the Moon could have formed. I think we're homing in on that now: we're looking at more subtle effects to see it *did* form as a result of a collision with another body with the Earth, very early on in its history.

SPACE TOURISM IS GETTING CLOSER AND CLOSER TO BECOMING A REALITY. WOULD YOU GO INTO SPACE, AND WHERE WOULD YOU GO?

Oh yes, I would definitely go into space if I could! I'd go anywhere somebody would take me, really, but I'd love to explore the Moon. When you look at pictures, it looks grey, very black and white. Is it like that really? Or would you see more colours in the rocks?

WHAT DO YOU THINK THE FUTURE HOLDS FOR BRITISH AND EUROPEAN SPACE EXPLORATION?

If you're referring to Brexit, the European Space Agency isn't an arm of the European Union or the European Commission – it's completely separate. So as long as we keep paying our subscription to ESA, then we will have access to space missions. As long as we keep funding our space agency and our research community, we will be able to plan space missions and get the benefit of the data and the technology spin-offs.

Now, if we remained a member of the EU, there are even bigger opportunities. Things like the next generation of GPS satellites – which we invested a huge amount of money in to design and to build.

WHAT MAKES YOU HOPEFUL FOR SPACE SCIENCE AND THE FUTURE OF THE INDUSTRY?

Babies keep being born! So that's more potential scientists and engineers. Look at a child as they develop: they are curious and they want to explore their world. We have to keep that sense of wonder and wanting to explore, and make sure we treasure it. That's really important.

PROF MONICA GRADY

Monica is professor of planetary and space sciences at the Open University, and a research fellow at the Natural History Museum.

Interview by* BBC Science Focus *editorial assistant Amy Barrett.

DISCOVER MORE

You can listen to podcasts about space at ***sciencefocus.com/science-focus-podcast***

GETTY IMAGES

PICK OF THE EVENTS

SPACE DAY 2019
THE HIVE, SAWMILL WALK, WORCESTER
SAT 5 OCTOBER, 10.30AM-4PM

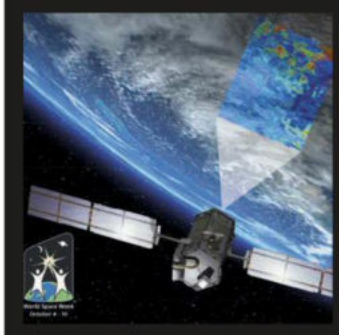
The British Interplanetary Society hosts the UK's biggest free space exhibition. Exhibitors include the Institute of Physics, the European Space Agency and Spaceflight UK.

bit.ly/space_day_2019

AN AUDIENCE WITH DR DON THOMAS
GEORGE HOTEL, LICHFIELD
MON 7 OCTOBER, 7PM

Dr Don Thomas, the four-time Space Shuttle astronaut turned author and science educator. will give a lecture on his experiences in space and his current activities, followed by a Q&A session. Over 16s only.

bit.ly/don_thomas



1969 AND ALL THAT
DYNAMIC EARTH, HOLYROOD RD, EDINBURGH
TUE 15 OCTOBER, 7PM

Prof Monica Grady will be giving a lecture about "all the things that happened in 1969 to do with planetary sciences – meteorites in Antarctica, comet 67P, the Marina space probe pictures – as well as Neil Armstrong landing on the Moon."

bit.ly/Monica_talk

3... 2... 1... ACTION!

CHRIS'S PICK OF THE ESSENTIAL KIT THAT'LL GIVE YOUR YOUTUBE VIDEOS PROFESSIONAL POLISH

MANFROTTO BEFREE ALUMINIUM TRAVEL TRIPOD

If you're planning on taking your DSLR out and about for shooting, I highly recommend grabbing a Manfrotto tripod. This aluminium effort folds up impressively small, and is incredibly light to boot, yet there's no compromise on stability. Perfect for throwing in a backpack, or taking on trips abroad.

£185, MANFROTTO.COM

PANASONIC GH5

If you want a dependable DSLR for shooting 4K video by yourself, the Panasonic GH5 is still a winner. It's easy to use, boasts impressive stabilisation and packs in a surprisingly deep range of features for a reasonable price. Just remember to grab a spare battery if you're shooting a lot of footage.

£1,500, PANASONIC.COM/UK

FINAL CUT PRO X

If you're serious about producing a professional video and you own a Mac, then check out *Final Cut Pro*. It's a surprisingly intuitive but feature-packed editor, allowing you to layer 4K clips and other media. You can add transitions and other effects simply by dragging and dropping onto the timeline. Alternatively, if you just want to trim your video clips, check out the simpler (and free) *iMovie*.

£299.99, APPLE.COM

JOBY GORILLAPOD MOBILE RIG

If you're keen to shoot videos with your smartphone or GoPro, then check out the GorillaPod. This flexible little fella can stand your mobile device upright on a desk for convenient hands-free shooting. Alternatively, those bendy legs can wrap around a post, handlebars and other slim objects, giving you full freedom.

£70, JOBY.COM

RODE LAVALIER MIC

To capture decent quality audio, you'll need a dedicated external microphone. Thankfully, they're pretty affordable. Rode's Lavalier microphones clip to your lapel and cleanly pick up your voice, even when you're stood a distance from the camera in blustery conditions. Rode also offers a range of other mics to suit all needs, including some designed for smart-phones if you want to shoot on the cheap.

FROM £47, RODE.COM

Troubleshoot

MAKING A YOUTUBE CHANNEL

FANCY HAVING A GO AT VLOGGING? TECH JOURNALIST AND AVID YOUTUBER CHRIS BARRACLOUGH SAYS IT'S EASIER THAN YOU THINK...

WHY SHOULD I START MY OWN YOUTUBE CHANNEL?

There are all kinds of different reasons for starting up your own YouTube channel. Some people do it to share their passions and knowledge with the world. Others simply want to vent about life's little annoyances.

If you have a particular talent, be it playing an instrument or even playing video games, YouTube is a great way to advertise yourself and grow a following. Some of the more popular YouTubers are watched by millions of people every month, while the biggest vloggers are now fully-fledged celebrities with their own clothing brands and sponsorship deals.

YouTube reaches almost two billion people each month in over 90 countries, making it one of the biggest virtual stages on the internet. So whatever you want to make videos about, you're sure to find an audience.

HOW MUCH TIME DOES IT TAKE?

Managing a channel can take as little or as much time as you like. Hardcore YouTubers post a video every day, while others upload whenever they have a chance. However if you're hoping to build a dedicated following, it definitely helps to stick to a regular schedule. Even if it's just one video a week, posted on the same day.

Of course, the amount of time you'll spend creating each individual video really depends on your subject matter. If you're putting together a directorial masterpiece involving on-location shooting, complex camera angles and special effects, you might be on it for days. If you're basically going to rant at the camera about how rubbish everything is, you could be done in just a few minutes.

WILL I NEED TO BUY EXPENSIVE EQUIPMENT?

Not at all. Even the most basic smartphones these days can shoot Full HD video, while many can record at 4K resolution too. So if you're working to a tight budget, you can get away with spending little to nothing. If you're planning on shooting with your mobile, you can grab some accessories to help out. I'd recommend buying a smartphone tripod to hold the handset in any position you require, while you can also improve the audio quality with a plug-in mic.

If you're serious about quality, try a DSLR camera. I use the Panasonic Lumix GH5, which is a couple of years old now, but still fantastic for video. Otherwise, if you want to shoot your more active exploits with hands-free convenience, you can't go wrong with a GoPro.

GOT ANY QUICK TIPS FOR IMPROVING VIDEO QUALITY?

The two most important things to consider are lighting and audio. You should always shoot in a well-lit environment, and if you can't afford studio lighting, try using natural illumination from a window. Just remember not to shoot against the light, or else you'll appear as a murky mess.

For good quality audio, get a lapel mic and shoot your videos in a spacious room filled with furniture. Those uneven surfaces will help to prevent any pesky echo. If you have to shoot outdoors, get a mic with a muffler – sometimes rather horrifically referred to as a 'dead cat' – to dampen wind interference.

"If you're hoping to build a dedicated following, it definitely helps to stick to a regular schedule"

DO I NEED TO LEARN HOW TO EDIT VIDEO?

Editing video can seem like an incredibly daunting task if you've never attempted it before. Most editing apps such as *Final Cut Pro* and *Premiere Pro* are a hot mess of windows, menus and incomprehensible jargon, but don't despair. You'll find plenty of stripped-down, simplified editors out there, such as *iMovie* on MacOS and *VideoPad* on Windows, which come complete with built-in tutorials. These allow you to quickly trim and stick together clips, which is all that most YouTubers will ever need to do. Just remember to save your finished video in a YouTube friendly format, such as MOV.

If you're brave enough, you can even stream live to YouTube using your smartphone. Not only does that cut out the need for editing, but your viewers can actually interact with you, asking questions or throwing out comments. You have been warned!

CHRIS BARRACLOUGH (@seebaruk)
Chris is a tech journalist and creator of the YouTube channel Tech Spurt, which reviews gadgets, phones, computers, wearables and apps.
youtube.com/techspurt

RECOMMENDED

FIND OUT WHAT'S CAUGHT OUR ATTENTION THIS MONTH

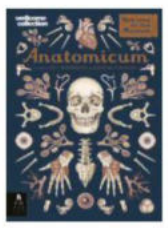
WHAT I'M READING

Amy Barrett

EDITORIAL ASSISTANT

ANATOMICUM

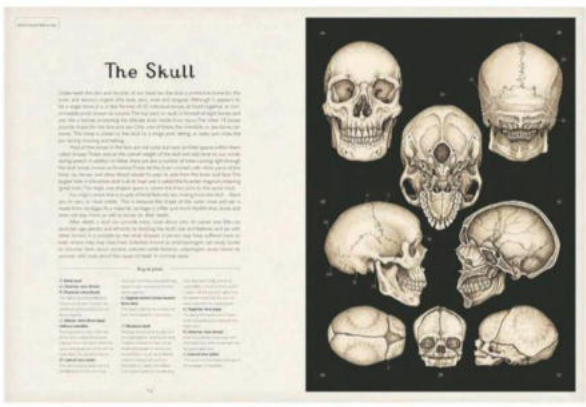
CURATED BY KATY WIEDEMANN AND JENNIFER Z PAXTON (£25, BIG PICTURE PRESS, IN ASSOCIATION WITH WELLCOME COLLECTION)



This is a museum quite unlike any other. The incredible world of the human body is displayed in print across six 'galleries'.

A favourite page of mine shows the bust of a woman with a diamond-shaped section of skin cut away from her abdomen, revealing the wonder of the urinary system underneath. The Cardiovascular and Respiratory Systems gallery features a detailed dissection of the heart, where I can identify the valves, open and closed. The *lub-dub*, *lub-dub* of each heartbeat is almost echoed in the turning of the large, thick pages.

This is a book I would be proud to put on my coffee table. I can imagine inviting guests to sit, step inside the *Anatomicum* and choose their favourite image after much consideration. Just be careful – no food or drink near the museum, please.



WHAT I'M PLAYING

Daniel Bennett

EDITOR

TELLING LIES

£15.49

AVAILABLE VIA STEAM, ON MAC & PC

If you love a whodunnit, try out a game called *Her Story*. It's not a traditional video game. You don't shoot anyone, smash anything up or jump on any turtles, instead, *Her Story* mimics an old police computer that you search through to investigate a cold case. You use search terms, like 'murder' to dig up old interrogation footage of live actors and piece together a story told out of order. The trick is to identify what's important, and what's not, and use your guile to recreate the timeline of events. The beauty of this formula is that every player enjoys a different experience.

In *Telling Lies*, *Her Story's* creator Sam Barlow expands on this format, replacing the police computer with an NSA database that the player uses to spy on four characters embroiled in a deadly incident. This time, the game has bigger scope, recognisable actors and more drama. It's a thrilling experiment in story-telling that pays off and invites you back even after you've finished the game. I can't wait to see what Barlow does next.

WHERE I'M VISITING

Sara Rigby

ONLINE ASSISTANT

THE ART OF INNOVATION: FROM ENLIGHTENMENT TO DARK MATTER

SCIENCE MUSEUM, LONDON

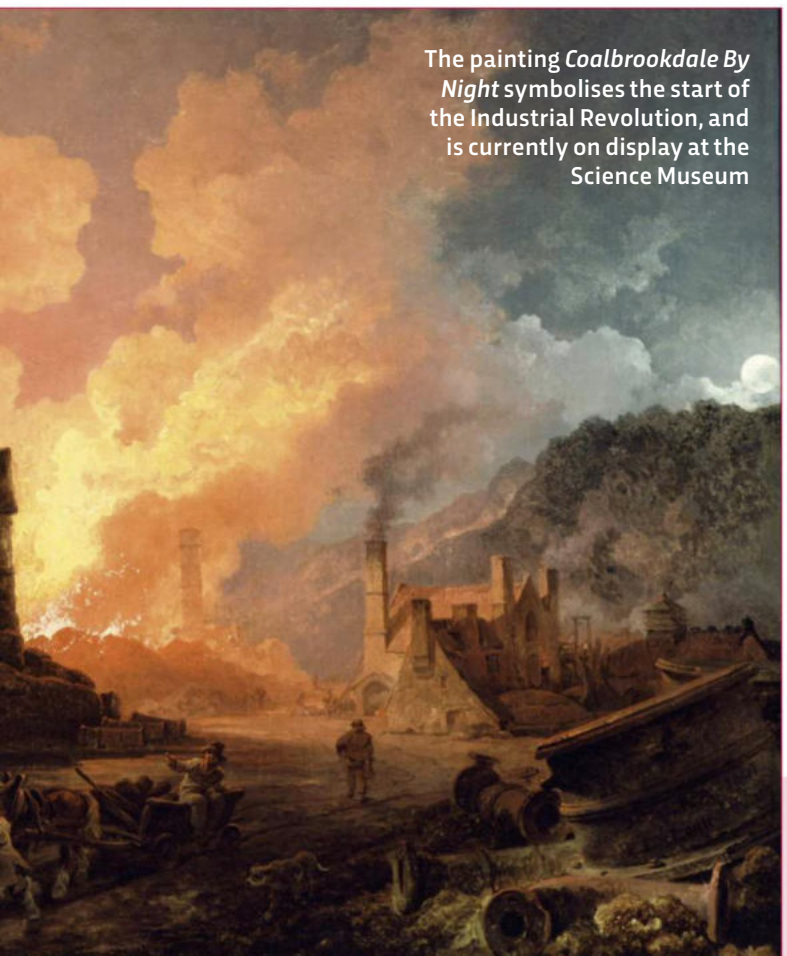
25 SEPTEMBER 2019 – 26 JANUARY 2020

We tend to think of science and art as polar opposites, but that certainly hasn't always been the case. Arguably, they share a common goal: understanding our place in the Universe.

The Art Of Innovation exhibition at London's Science Museum is an exploration of how the two fields have developed over the last 250 years: how is scientific discovery represented in art, and how has art driven scientific exploration? The exhibition features the work of artists such as Barbara Hepworth and David Hockney alongside

While experts usually encourage us to avoid blue light at bedtime, Dodow claims that its light is too dim to disrupt sleep

objects of scientific discovery. As well as the exhibition is BBC Radio 4's 20-part accompanying series, starting on 23 September, and a book of the same name, published on 19 September. Plus, subscribe to the *Science Focus Podcast* to catch our interview with principal curator Dr Tilly Blythe.



The painting *Coalbrookdale By Night* symbolises the start of the Industrial Revolution, and is currently on display at the Science Museum

WHAT I'M TESTING

Alice Lipscombe-Southwell
PRODUCTION EDITOR

DODOW

£49, DODOW.COM

Do you often lie in bed, staring at the ceiling, desperately trying to nod off? Or do you wake up at 3am with your mind racing at a million miles an hour? Dodow promises to get your sleeping back on track by encouraging deep breathing techniques to help you unwind. The discreet, wireless device sits on your bedside table and with a tap of your finger it projects a gentle beam of blue light that contracts and expands for eight minutes. The idea is that you breathe in rhythm with the light: inhaling on the expansion; exhaling on the contraction. Dodow claims that this gradually slows your breathing to six breaths per minute, therefore putting you in a relaxed state,

while fixating on the hypnotic blue light helps to calm any mental chatter. But does it work? After waking up in the all-too-familiar early hours, I turned the Dodow on. As promised, it helped me chill out, but I was still lying awake two hours later.

Still, it comes with a 100-day money-back guarantee if you aren't satisfied, so perhaps it's worth a try if the lavender baths and mugs of warm milk just aren't cutting it.

DISCOVER MORE

SQUEEZE EXTRA JUICE OUT OF THE TOPICS IN THIS ISSUE OF *BBC SCIENCE FOCUS* WITH THESE BOOKS, WEBSITES AND SHOWS

Reality check *p32*

HOW TO REDUCE YOUR CARBON FOOTPRINT WHEN YOU FLY

AVAILABLE ON BBC IPLAYER

In this episode of *The News Explained*, BBC environment reporter Laura Foster explains how you can keep your flight's carbon footprint to a minimum.

GLOBAL BUSINESS: FLYING GREEN

Can airlines go green? Is the future of air travel electric, biofuel, or something else? Listen to this episode of weekly documentary *Global Business* on the BBC World Service.

A SCIENTIST'S GUIDE TO LIFE: HOW TO SMELL NICE

Dr Chris Callewaert, also known as Dr Armpit, offers a scientist's guide to dealing with body odour.

bit.ly/how_to_smell_nice

Eat yourself happy *p48*

THE DIET MYTH

BY PROF TIM SPECTOR

(£8.99, ORION PUBLISHING)

In this book from Prof Tim Spector, find out more about the science behind the food you eat. Discover why so many diets fail, why some people never put on weight and others just keep getting fatter. Clue: it's all down to your gut microbes.

I CONTAIN MULTITUDES

BY ED YONG

(£10.99, VINTAGE)

This award-winning book from Ed Yong takes you on a trip through the world of microbes. Find out how they protect us from disease, alter our behaviour and help us digest our food.

THE MICROBES WITHIN US

Did you enjoy Ed Yong's book? In this fascinating talk from the Royal Institution, he explores the microbes swarming around your body.

bit.ly/microbes_talk

Michael Mosley *p55*

THE DOCTOR WHO GAVE UP DRUGS

In these two clips from the BBC series *The Doctor Who Gave Up Drugs*, Dr Chris Van Tulleken finds out more about the effect of cold water on the body, and takes a patient with depression on an outdoor swim.

bit.ly/soothing_swim

bit.ly/shock_to_euphoria

Samantha Alger interview *p58*

POLLINATOR PARTNERSHIP

Bee researcher Samantha says that Pollinator Partnership is the 'go-to' place for information on pollinators these days. It is the largest non-profit in the world dedicated to protecting pollinators.

pollinator.org

A STING IN THE TALE: MY ADVENTURES WITH BUMBLEBEES

BY DAVE GOULSON

(£8.99, VINTAGE)

Though once native to our shores, the short-haired bumblebee is now extinct in the UK. Written by the founder of the Bumblebee Conservation Trust, this book dives into the past, present and future of the species.

How to smash an asteroid *p64*

HERA: OUR PLANETARY DEFENCE MISSION

In this rather dramatic video, astrophysicist and Queen guitarist Brian May reveals more about the Hera mission and how it will study the impact site on Didymoon.

bit.ly/hera_mission

THE DOUBLE ASTEROID REDIRECTION TEST (DART)

Here, Andy Rivkin and Andy Cheng of the DART project tell us more about the mission to smash into an asteroid.

bit.ly/dart_mission

Should you upgrade your brain? *p72*

ARTIFICIAL YOU

BY SUSAN SCHNEIDER

(£20, PRINCETON UNIVERSITY PRESS)

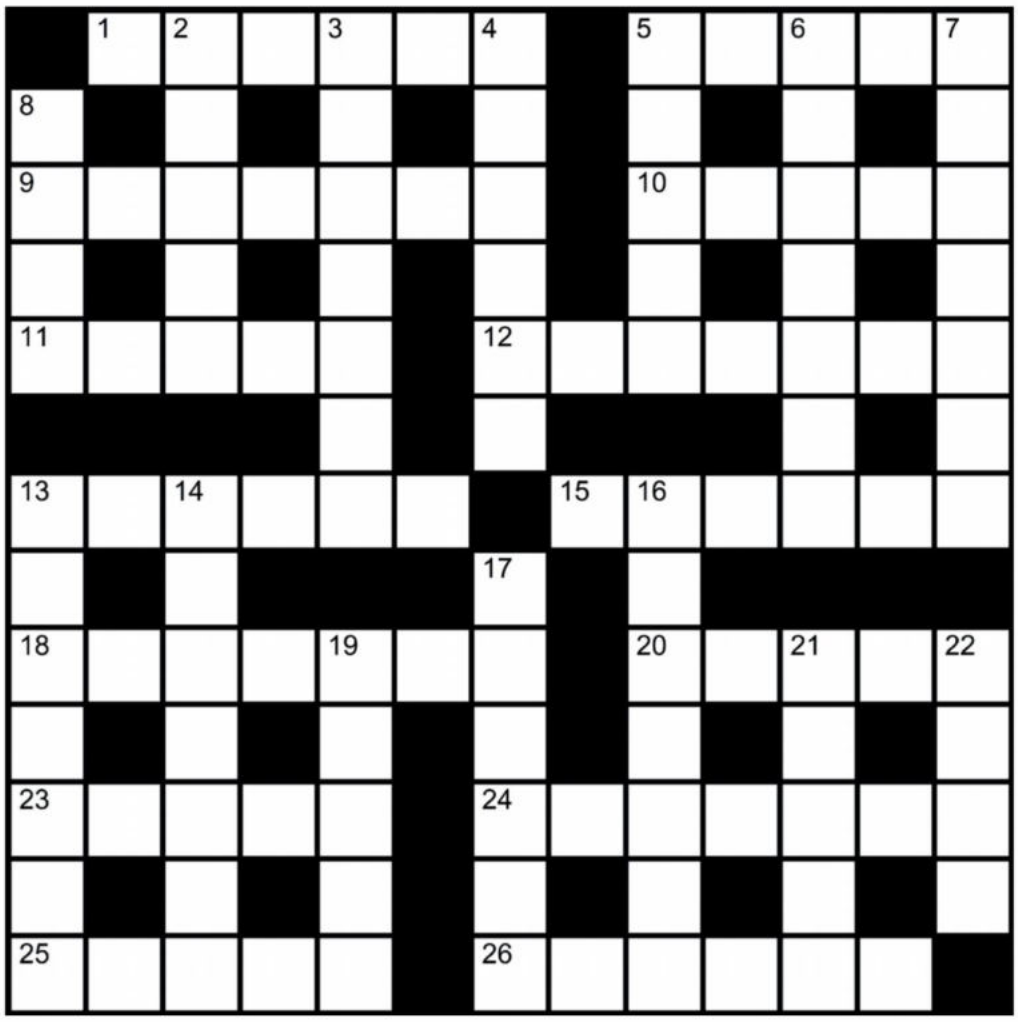
In her new book, out on 1 October, philosopher and cognitive scientist Susan Schneider explores the ways in which our minds and identities could be affected by future technology.

FOR MORE, FOLLOW US

@SCIENCEFOCUS

CROSSWORD

GIVE YOUR BRAIN A WORKOUT



ACROSS

1 Sailor gets a copper small calculator (6)
5 Snoopy, say, doesn't start getting good score (5)
9 Opening with key, joining trendy court painter (7)
10 Keyboard is more than half artificial (5)
11 Reportedly swoon in deceptive move (5)
12 Monkey in train, travelling with mother (7)
13 Want to put writer in front of judges? Not initially (6)
15 Drunken males have first of cocktails – it's alcoholic (6)
18 Television around ancient city is not too bad (7)
20 A riot out of proportion (5)
23 Darts player's place acquires right colour (5)
24 Meaningless comment, and wife gets doctor back (7)
25 Towel wrapped around youngster (5)
26 Time and motion list (6)

DOWN

2 Unfinished northern sea dish (5)
3 Chap leaves one city for another (7)
4 Reason reconsidered as tiny (6)
5 Mopes about town (5)
6 Unbranded information on rice production (7)
7 Arranged the loan for alcohol (7)
8 Revolutionary fellow works in the kitchen (4)
13 Choose missing ending, playing cool instrument (7)
14 Warn about Harold being an animal (7)
16 Body part brings nobleman honour (7)
17 Land bear is confused (6)
19 Defeat gets student to cry (5)
21 The first raid organised by criminal gang (5)
22 Cattle showing one problem – getting cross (4)

GETTY IMAGES

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

TABOO SCIENCE

Is it right to use the findings from unethical medical research?

PLUS

WHAT IF WE FORGOT ABOUT FASHION?

BILL BRYSON

We talk to the legendary travel and science writer about his new book, *The Body: A Guide For Occupants.*

ON SALE 23 OCT

SF

A SCIENTIST'S GUIDE TO LIFE

PAIN-FREE SHOPPING

WORN DOWN BY THE DRUDGERY OF THE WEEKLY SHOP? RETAIL RESEARCHER **SIEMON SCAMELL-KATZ** IS HERE TO MAKE THE EXPERIENCE A LITTLE EASIER

IS THERE SCIENCE TO SHOPPING?

Absolutely. We were the first people to put cameras and eye tracking devices in stores to monitor where people go and what they look at. When we married this with brain scans, we were able to see the effect these activities have on decision making.

SHOULD I PRICE-CHECK?

The question is, do you want to have an easier shop or a cheaper shop? If you want an easy shop, continue on automatic pilot and accept that at some point in the past, you made a choice to say that's the sort of price you will pay for this product. Or, shop carefully and pay attention to the prices, but accept it will take two to three times longer.

HOW SHOULD I NAVIGATE AISLES?

Sideways! To properly shop a category, stop and turn to face the shelves. We have a bias to look slightly down, between waist and chest height, so scan the full height of the shelves, and work your way along. This will help you to check the prices and promotions.

SHOULD I WRITE A LIST?

People who shop without a list are more likely to buy impulsively. If you want to control your budget, write a list and stick to it. People who do this buy 15 per cent fewer items then those who don't.

BASKET OR TROLLEY?

We did an experiment in a convenience store and found that if people don't have a basket, they buy only what they can carry. If they have a basket, they buy more. We have this unconscious mentality that the size of the shop matches the size of the container. So, if we grab a trolley, we buy more.

SHOULD I BRING THE KIDS?

Do not take your children! They have the power to pester and influence what you buy. Managing them is stressful so you get distracted and end up forgetting things or buying the wrong stuff.

ONLINE VS INSTORE?

The websites for online stores tend to be poorly designed. There's the hassle of trying to build a shopping list, so people often start their shopping, then go away, come back and add to it. You end up spending more because the websites are difficult to navigate.

BIG WEEKLY SHOP, OR SMALLER TOP-UP SHOPS?

If you do small, frequent shops, you will spend more money and time than if you do a big weekly or monthly shop. But when we asked people how long they think they spend shopping, we found that people who do smaller shops underestimate the time it takes – so you feel like it takes less time than a big shop.

WHAT'S THE BEST TIME OF DAY TO SHOP?

Late morning because it's quietest, so you're less likely to get stressed or distracted. But don't go shopping hungry. You're twice as likely to impulse purchase if you're hungry.

ANY OTHER TIPS?

Our eye-tracking research shows that people are drawn to big displays. We think if it's a big display it must be a good brand, but be aware that brands pay for this level of prominence. SF

SIEMON SCAMELL-KATZ
Siemon is a retail researcher, self-proclaimed professor of shopping, and director of M Cloud, a shopper research and consultancy business. He is the author of The Art Of Shopping: How We Shop And Why We Buy *(£18.99, LID Publishing).*
Interviewed by Dr Helen Pilcher.

NEED TO KNOW...

1

Write a list and stick to it, especially if you are on a budget.

2

Do not take your kids with you, as they'll stress you out and you'll buy the wrong stuff.

3

Don't shop hungry, as you'll be more likely to buy things on impulse.

ILLUSTRATION: CARLOS ORTEGA

MrSpeakers

Introduce ÆON

"I encourage you to place the Aeon on your must audition list. You will be glad you did."

- Chris Martens
Hifi + Issue 147

"The Aeon is very possibly Mr Speaker's headphone masterpiece."

- Dave Hansen
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the sound connection
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